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LARGE-SCALE WIND-TUNNEL TESTS OF THREE VEHICLES INCORPORATING A DEPLOYABLE RIGID WING

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16. Abstract

Wind-tunnel tests were performed to determine the aerodynamic characteristics of three full-scale vehicles incorporating a unique folding metal wing, and to investigate its deployment characteristics. The static aerodynamic data are presented without analysis.

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NOTATION

b	reference span of wing
$\bar{c}$	reference chord of wing
C_D (or CD)	drag coefficient, D/qS
C_L (or CL)	lift coefficient, L/qS
C_l or CR	rolling-moment coefficient, $\frac{L}{q S b}$
C_m (or CM)	pitching-moment coefficient, $\frac{M}{q S \bar{c}}$
C_n (or CN)	yawing-moment coefficient, $\frac{N}{q S b}$
C_Y (or CY)	sideforce coefficient, Y/qS
D	drag, lbs
L	lift or rolling moment
M	pitching moment
N	yawing moment
q	free stream dynamic pressure
Re	Reynolds number based on $\bar{c}$, $\frac{V\bar{c}}{\nu}$
S	reference wing area
V	free stream velocity
α (or ALPHA)	angle of attack of wing chord line
β (or BETA)	sideslip angle
ψ (or PSI)	angle of yaw ($\equiv -\beta$)
δ_A	asymmetric aileron deflection (per surface), degrees (positive for right roll)
δ_T	symmetric surface deflection of "V" tails, degrees (positive T.E. down)
δ_R	asymmetric surface deflection of "V" tails, degrees (positive T.E. right)
ν	kinematic viscosity of free stream air

SUMMARY

Wind-tunnel tests were performed to determine the aerodynamic characteristics of three full-scale vehicles incorporating the same unique folding metal wing, and to investigate its deployment characteristics. Two of the vehicles represented drones or RPV's and the third represented a flying ejection seat (Aercab). The static aerodynamic data are presented here without analysis.

INTRODUCTION

A unique folding metal wing concept has been developed (ref. 1) which is being investigated by the U.S. Air Force for several possible applications. Tests of three full-size vehicles incorporating this wing concept were performed in the Ames 40- by 80-Foot Wind Tunnel to determine their aerodynamic characteristics at full-scale Reynolds numbers, and to investigate deployment and control capabilities at representative speeds.

The first two configurations tested were representative of RPV's or target drones. The third vehicle tested was representative of a flying ejection seat (Aercab).

MODEL DESCRIPTION

Photographs of the models installed in the wind tunnel with wings extended are shown in figures 1(a), (b), and (c); figure 1(d) shows configuration I with the wings folded. Two-view sketches of the models are shown in figures 2(a), (b), and (c). A diagram of the wing deployment sequence is presented in figure 2(d). A description of the folding and deployment mechanism is given in reference 1. Dimensional information is given in table 1.

The same wing was used for all configurations. However, its span was varied slightly by extending the telescoping spar carry-through structure at the wing root to match the root rib to the side of each fuselage. A common set of reference dimensions was used to reduce the data for all three configurations, as shown in table 1.

TESTS AND CORRECTIONS

Tests to determine the aerodynamic characteristics of the vehicles were run for each of the three configurations, as listed in table 2. Deployment tests were also conducted and recorded on film and video tape.

Correction for wind-tunnel wall effects were not applied to the data because they were so small as to be within the limits of error of the measuring devices. The data were carefully corrected for the support system tares, however.

The nominal dynamic pressure for these tests was 60 lb/sq ft (28.7 N/m^2), corresponding to a Re of 3.6×10^6 based on the wing chord. Additional runs were made at dynamic pressures of 20, 40, and 85 lb/sq ft (Re = 2.3, 2.9, and 4.2×10^6), to determine the effect of Re.

RESULTS

The principal static aerodynamic data are presented without analysis in figures 3, 4, and 5. Forces are presented in wind axes and moments about stability axes with the center located on the wing chord line $0.25\bar{c}$ from the leading edge. Figure 3 shows the aerodynamic data for configuration I, figure 4 the aerodynamic data for configuration II, and figure 5 the aerodynamic data for configuration III. The dynamic pressure, q, in pounds per square foot, is noted on each figure; the nominal q, used for most runs, was 60 (18.7 N/m^2). An index to the data figures is presented in table 2, which is given in lieu of detailed figure titles.

Wing deployments from the full folded position were attempted on configurations I and II at zero airspeed and at airspeeds up to about 80 knots (40 m/s). These were recorded on film and on video tape which have been submitted to the U.S. Air Force (PDL, WPAFB). Visual observations of the deployments demonstrated that the basic design concept appeared to be sound. Several of the deployments were incomplete, particularly those at the higher dynamic pressures and/or higher angles of attack. Many of the problems encountered were due to simple mechanical malfunctions typical at this stage of a concept development.

REFERENCE

1. Gleason, Laurence L.; and Osborn, Russel F., Jr.: Design and Wind Tunnel Testing of a Deployable/Retractable Rigid Wing Semispan. Technical Report AFFDL-TR-72-112, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, May 1973.

Table 1. Dimensional Data

General

Reference Wing Area, S = 41.67 sq ft (3.871 m^2)

Reference Span, b = 16.67 ft (5.080 m)

Reference Chord, $\bar{c}$ = 2.500 ft (0.762 m)

Aileron Area = 1.58 sq ft (9.147 m)

Aileron Span = 2.375 ft (0.724 m)

Aileron Chord = 0.667 ft (0.203 m)

Configuration I

Wing Area = 42.50 sq ft (3.948 m^2)

Wing Span = 17.0 ft (5.182 m)

Overall Length = 28.58 ft (8.711 m)

Tail Length = 10.46 ft (3.188 m)

Max Fuselage Width = 2.33 ft (0.710 m)

Wing Incidence = 3.0°

Projected Area, Horizontal Tail = 16.69 sq ft (1.551 m^2)

Projected Area, Vertical Tails = 10.51 sq ft (0.976 m^2)

Configuration II

Wing Area = 41.67 sq ft (12.701 m)

Wing Span = 16.67 ft (5.081 m)

Overall Length = 19.17 ft (5.843 m)

Tail Length = 10.76 ft (3.280 m)

Max Fuselage Width = 1.96 ft (0.597 m)

Wing Incidence = 3.0°

Projected Area, Horizontal Tail = 5.44 sq ft (0.505 m^2)

Projected Area, Vertical Tail = 3.33 sq ft (0.309 m^2)

Table 1 (cont.)

Configuration III

Wing Area = 41.54 sq ft (3.859 m^2)

Wing Span = 16.62 ft (5.066 m)

Overall Length = 12.50 ft (3.810 m)

Tail Length = 7.86 ft (2.396 m)

Max Fuselage Width = 1.58 ft (0.482 m)

Wing Incidence = 0°

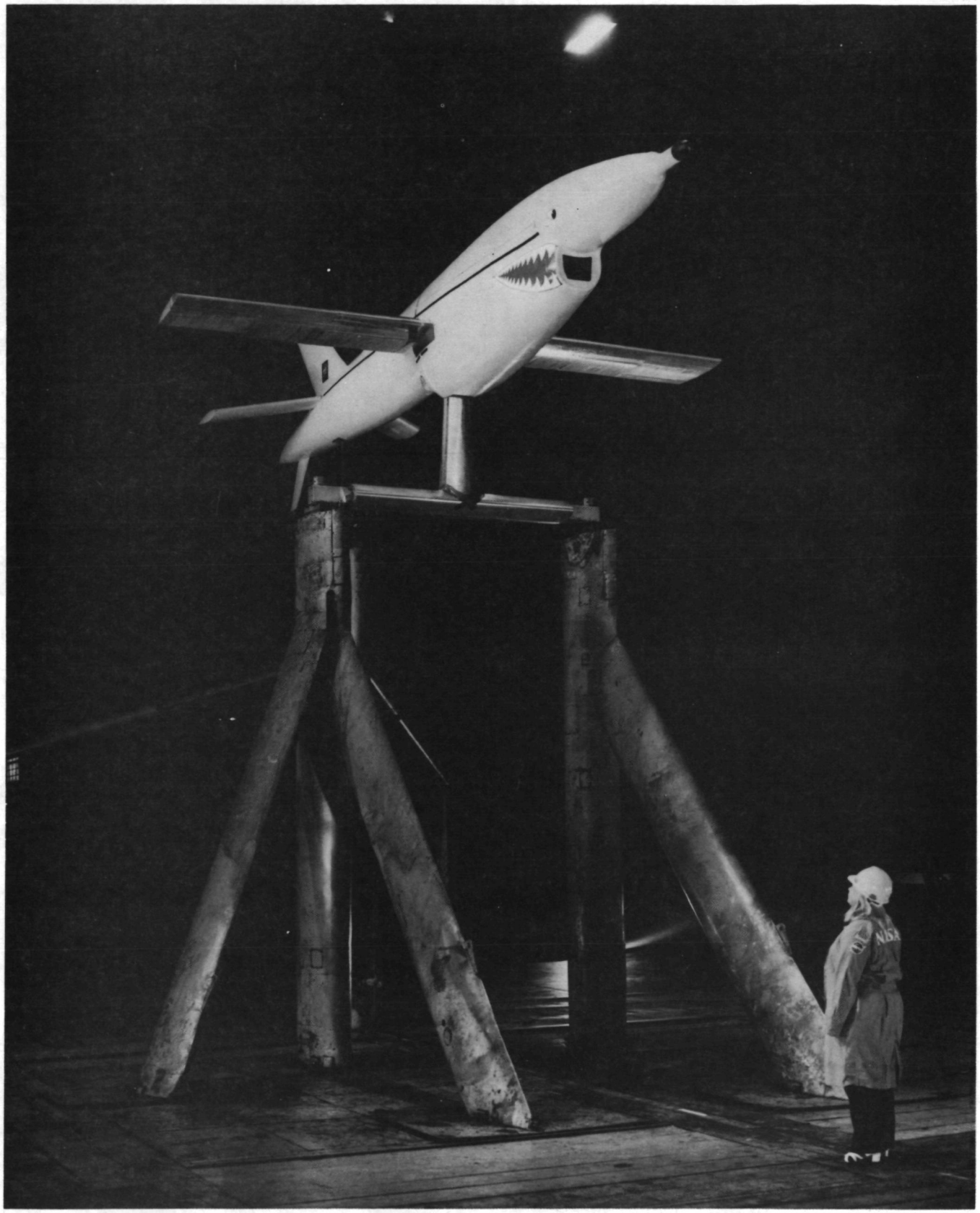
Projected Area, Horizontal Tail = 2.87 sq ft (0.276 m^2)

Projected Area, Vertical Tails = 2.24 sq ft (0.208 m^2)

Projected Tail Surface Areas = 3.67 sq ft (0.34 m^2)

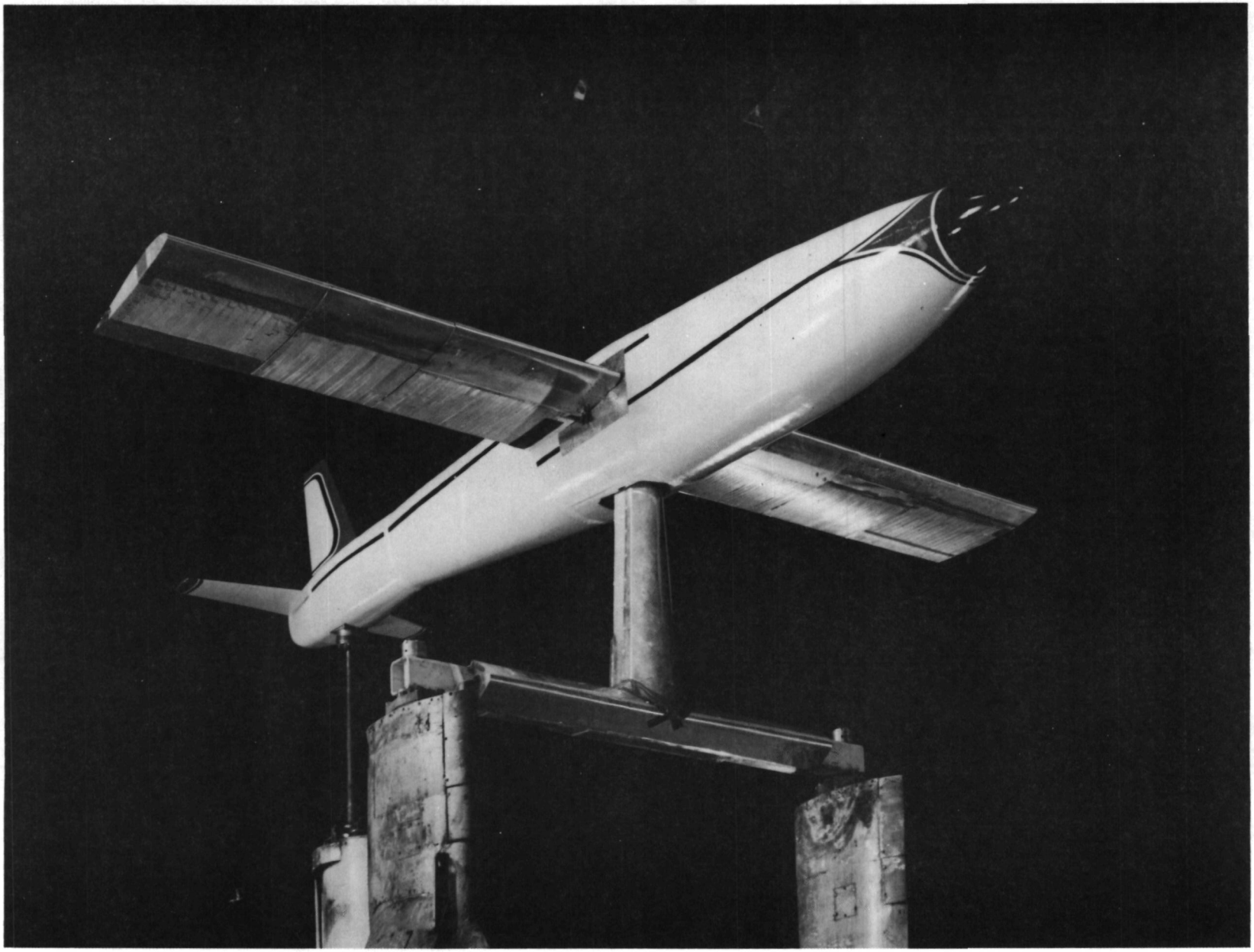
Table 2. Index of Data Figures

Config.	Fig. no.	Run numbers	Primary variable(s)	Remarks	Parameters ($q \cong 60$ except as noted)
I	3a	7,8,6,4/5	α	Base Data, Re Effect	q = 20, 40, 60, 85
	b	7,9,10,13	α, ψ	Base Data, Re Effect	$\psi = -10, 0$; q = 20, 40, 60
	c	16,14,15,22	ψ	Base Data	$\alpha = 0, 3, 7$; q = 60
	d	17,11,18	δ_A	δ_A Effect	$\psi = 0$; $\alpha = 0, 3, 7$; q = 60
	e	17,12,19	δ_A	δ_A Effect	$\psi = 0, -10$; $\alpha = 0, 3$; q = 60
	f	7,20,21	α, ψ	Folded Wings	$\psi = 0, -10$; q = 60
II	4a	30,28,29,31	α,ψ	Base Data, Re Effect	$\psi = 0; -10$; q = 40, 60
	b	33,32,34,27	ψ	Base Data	$\alpha = 0, 3, 7$; q = 60
	c	35,36,37	δ_A	δ_A Effect	$\alpha = 0, 3, 7$; $\psi = 0$; q = 60
	d	39,40,41	δ_A	δ_A Effect	$\alpha = 0, 3, 7$; $\psi = -10$; q = 60
	e	30,24,25,26	α, ψ	Folded Wings	$\psi = 0, -10$; q = 60
III	5a	44,42,43,45	α, ψ	Base Data, Re Effect	$\psi = 0, -10$; q = 40, 60
	b	47,46,48	ψ	Base Data	$\alpha = 0, 3, 7$; q = 60
	c	49,50,51	δ_A	δ_A Effect	$\psi = 0$; $\alpha = 0, 3, 7$; q = 60
	d	52,53,54, 58,63	δ_A	δ_A Effect	$\psi = -5$; $\alpha = 0, 3, 7$; $\psi = +5$; $\alpha = 3$
	e	55,56,57	δ_A	δ_A Effect	$\psi = -10$; $\alpha = 0, 3, 7$; q = 60
	f	44,59,62	α	Tails Off, Base Data	$\psi = 0$; q = 40, 60
	g	48,46,60,61	ψ	Tails Off, Base Data	$\alpha = 0, 7$; q = 60
	h	44,65,66,67, 68,69	α, δ_T	Elevater Effect	$\delta_T = 0, 0, +10, -5, -10, -15$
	i	44,70,73,76	α, δ_R	Rudder Effect	$\delta_R = 0, -5, -10, -15$
	j	48,46,71,72, 74,75	ψ, δ_R	Rudder Effect	$\delta_R = 0, -5, -10$; $\alpha = 0, 7$



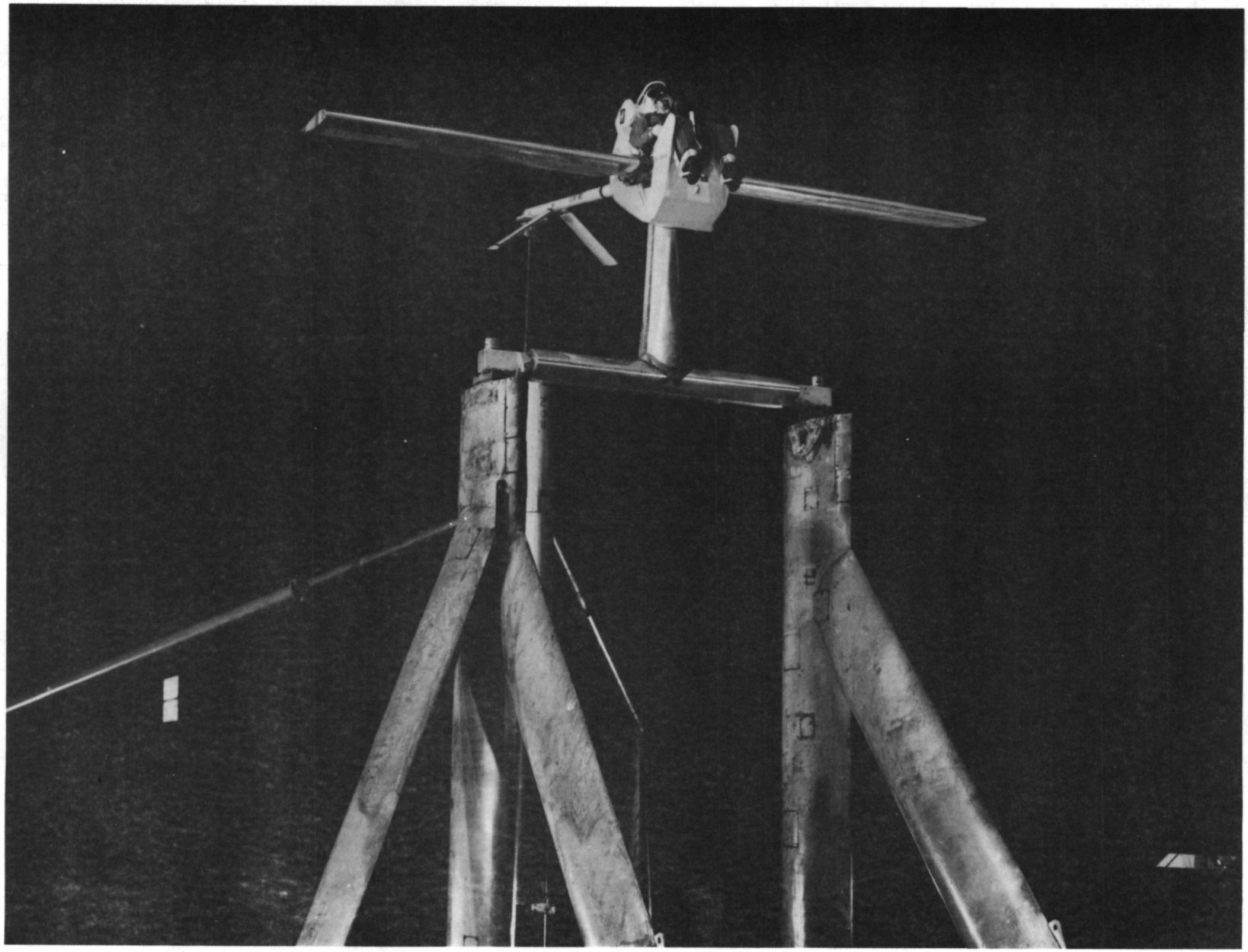
(a) Configuration I.

Figure 1.— Photographs of configurations mounted in the Ames 40- by 80-Foot Wind Tunnel.



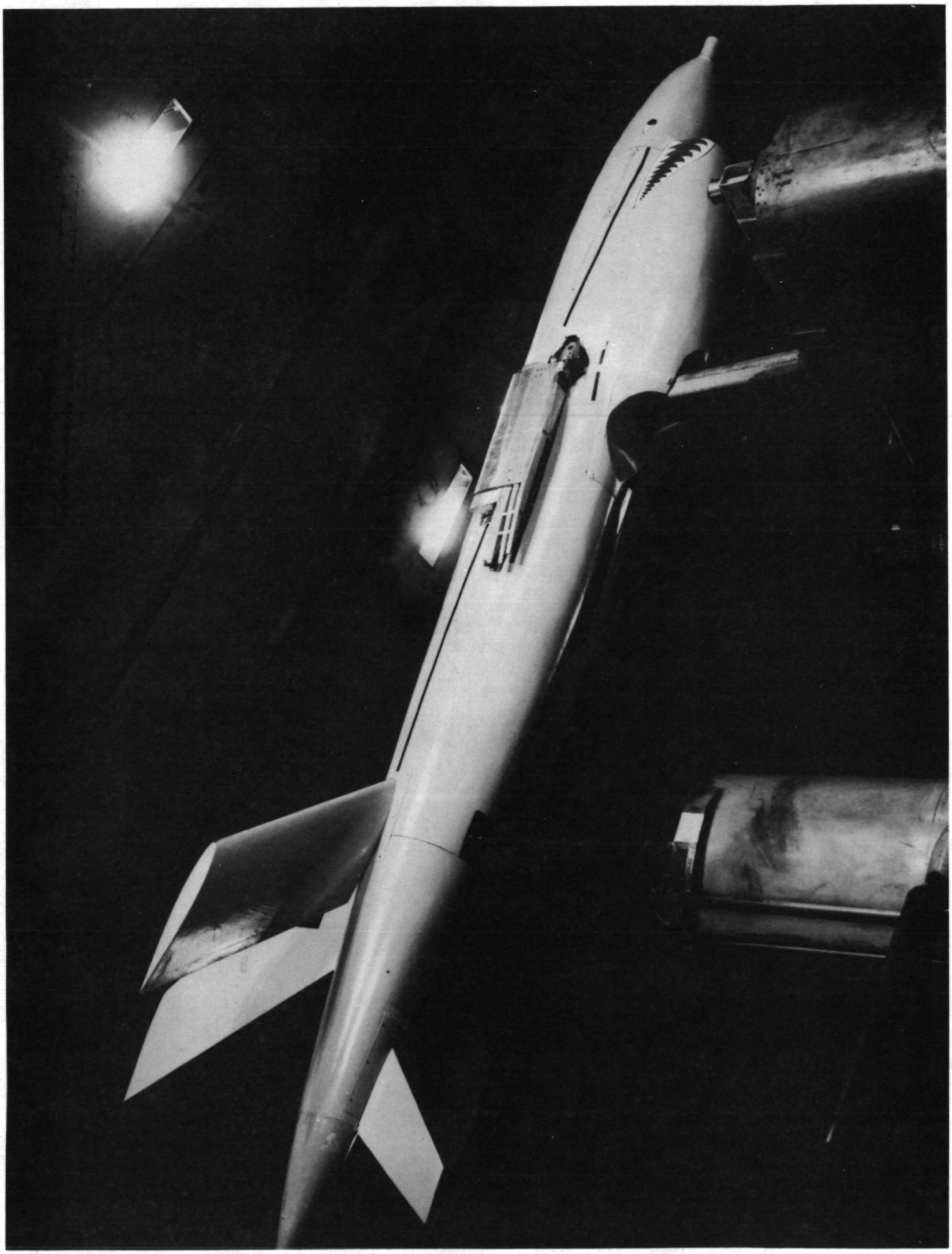
(b) Configuration II.

Figure 1.– Continued.



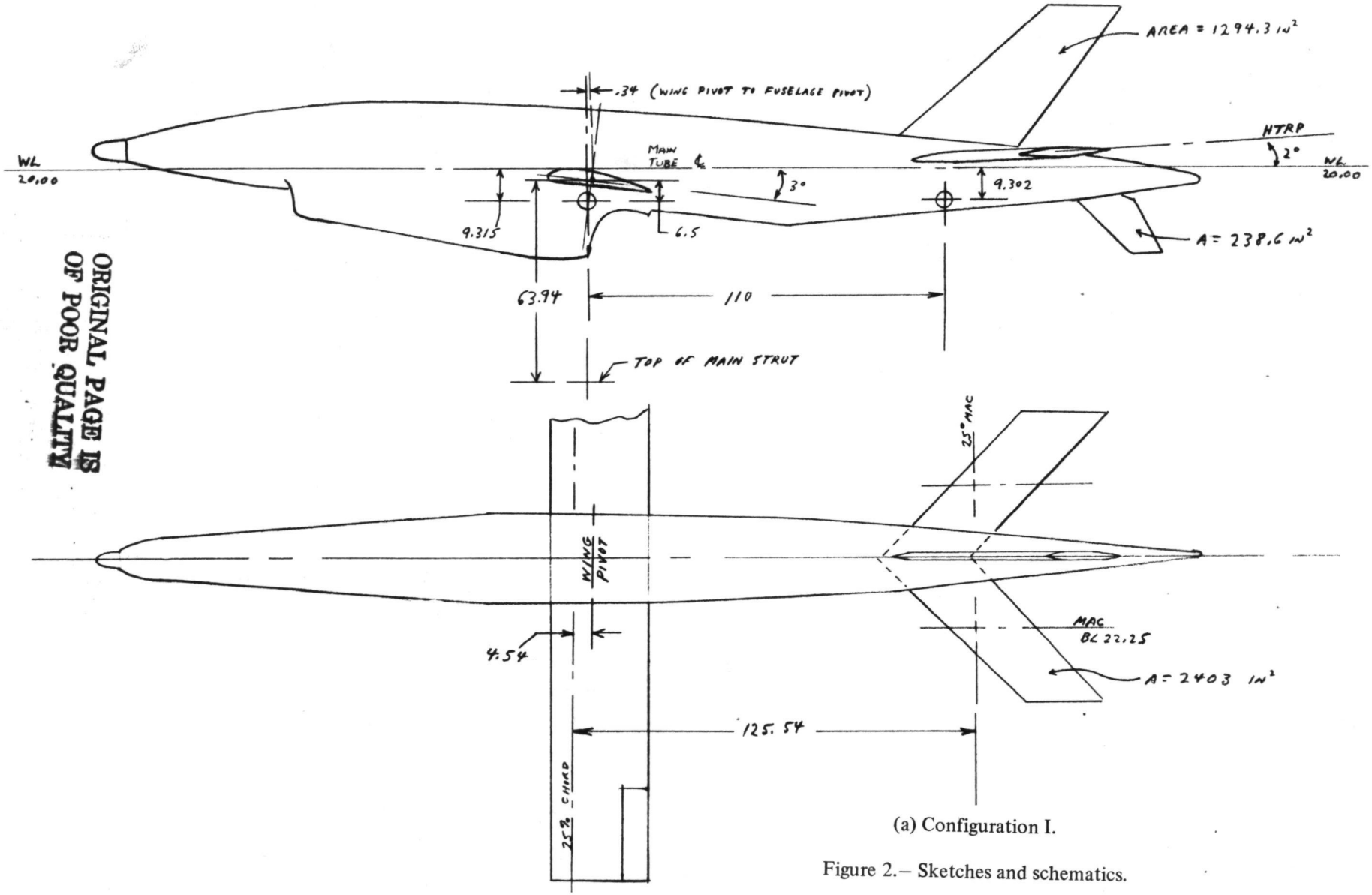
(c) Configuration III.

Figure 1.– Continued.



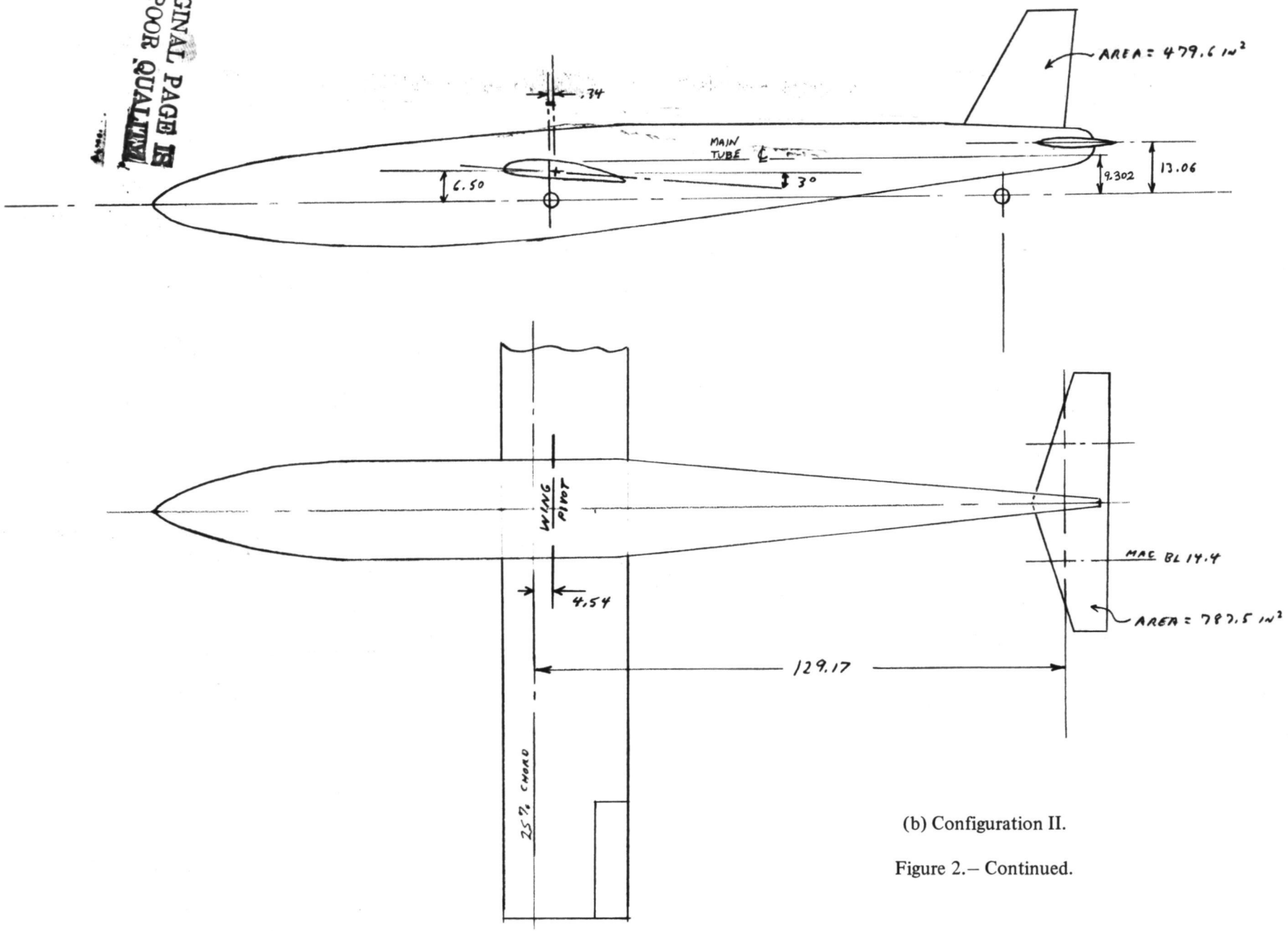
(d) Configuration I with wings folded.

Figure 1.– Concluded.



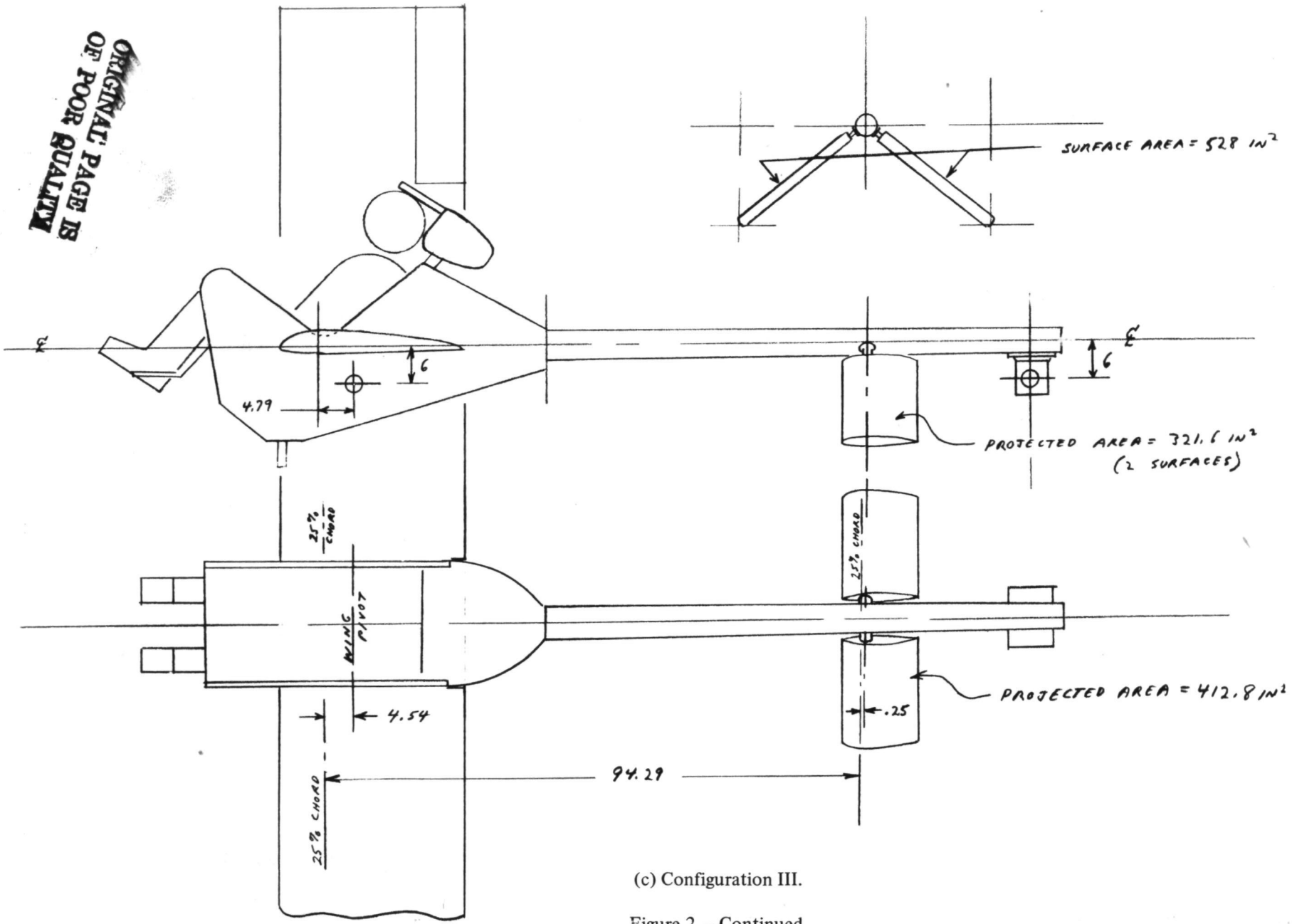
(a) Configuration I.

Figure 2.– Sketches and schematics.



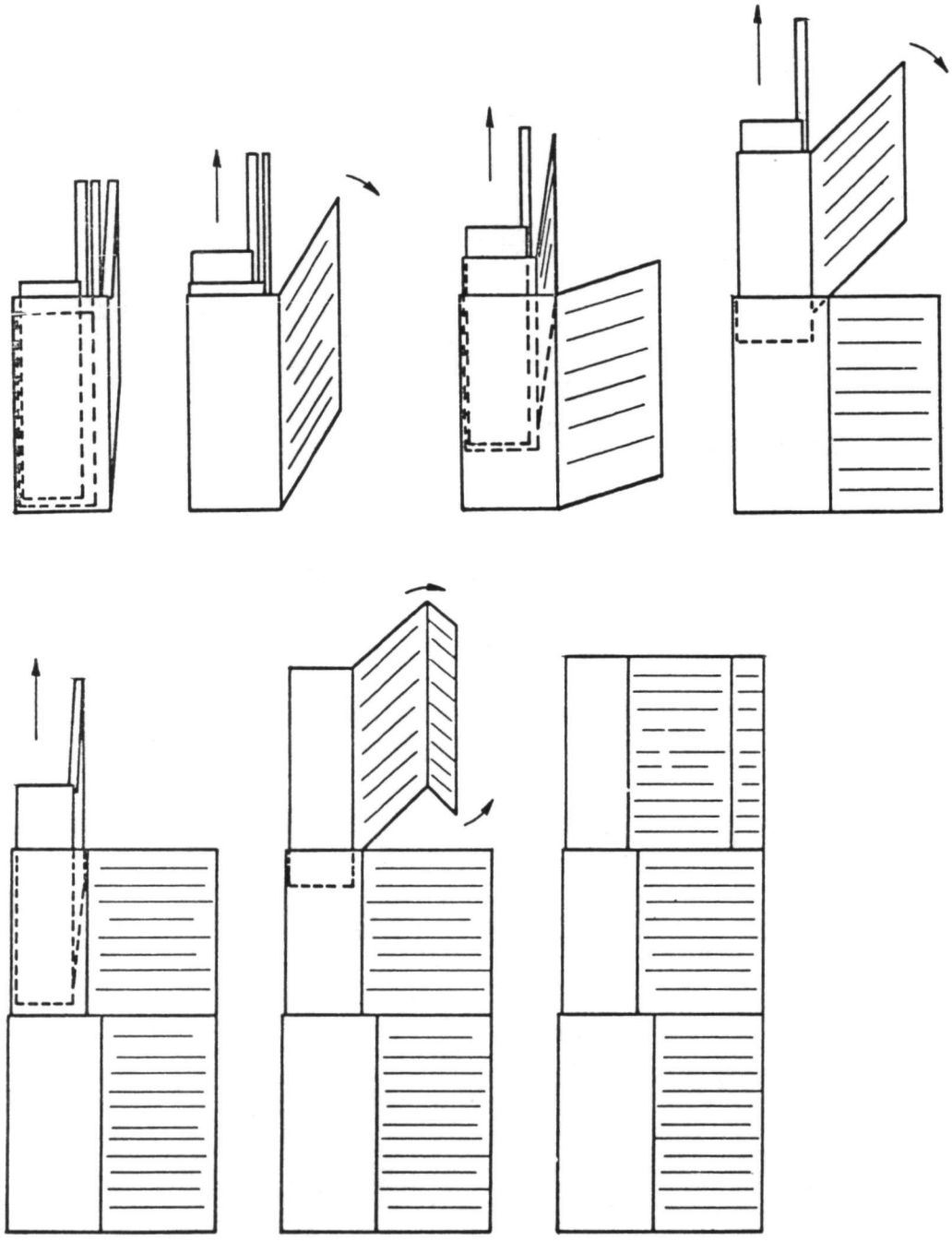
(b) Configuration II.

Figure 2.– Continued.



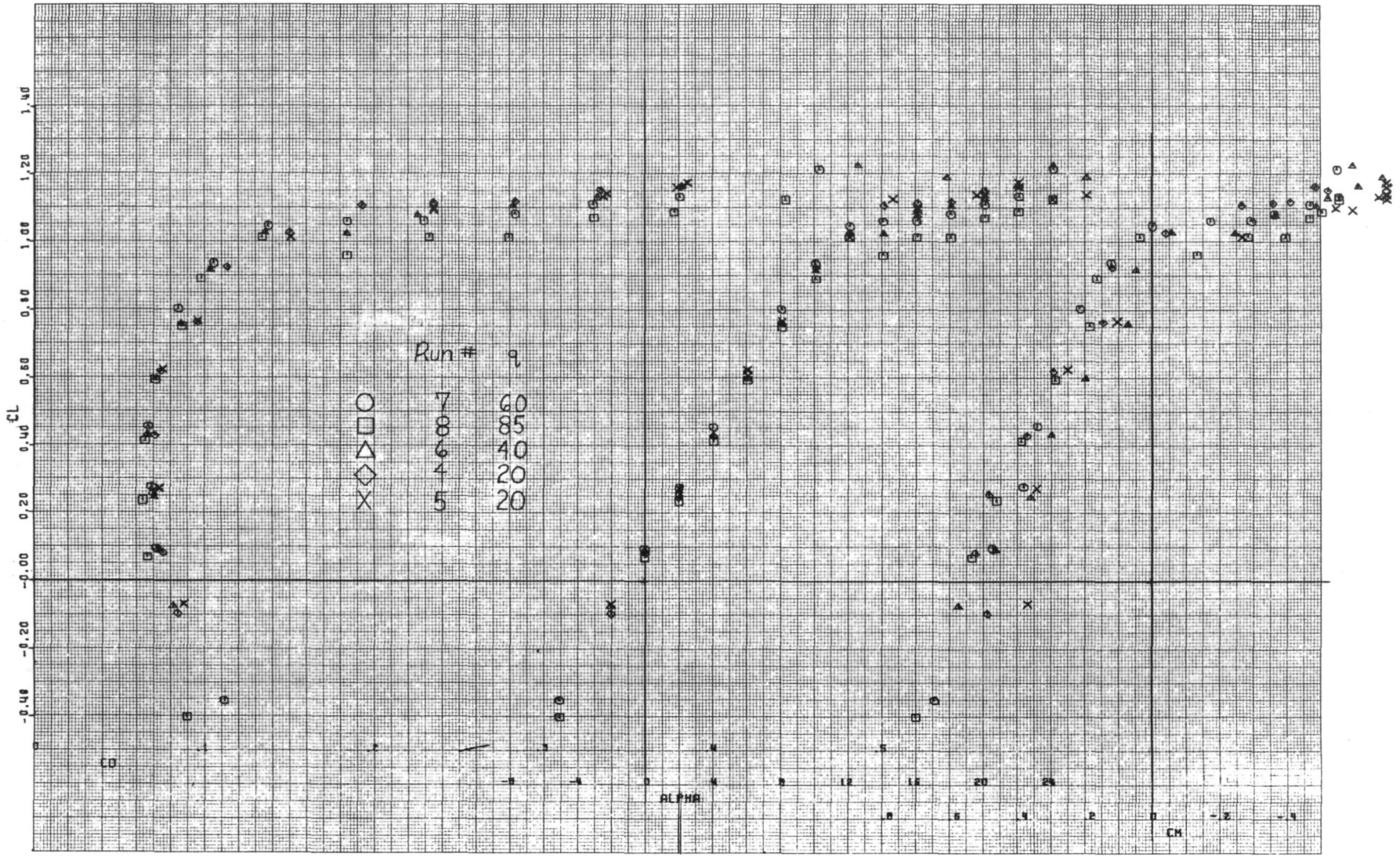
(c) Configuration III.

Figure 2.– Continued.



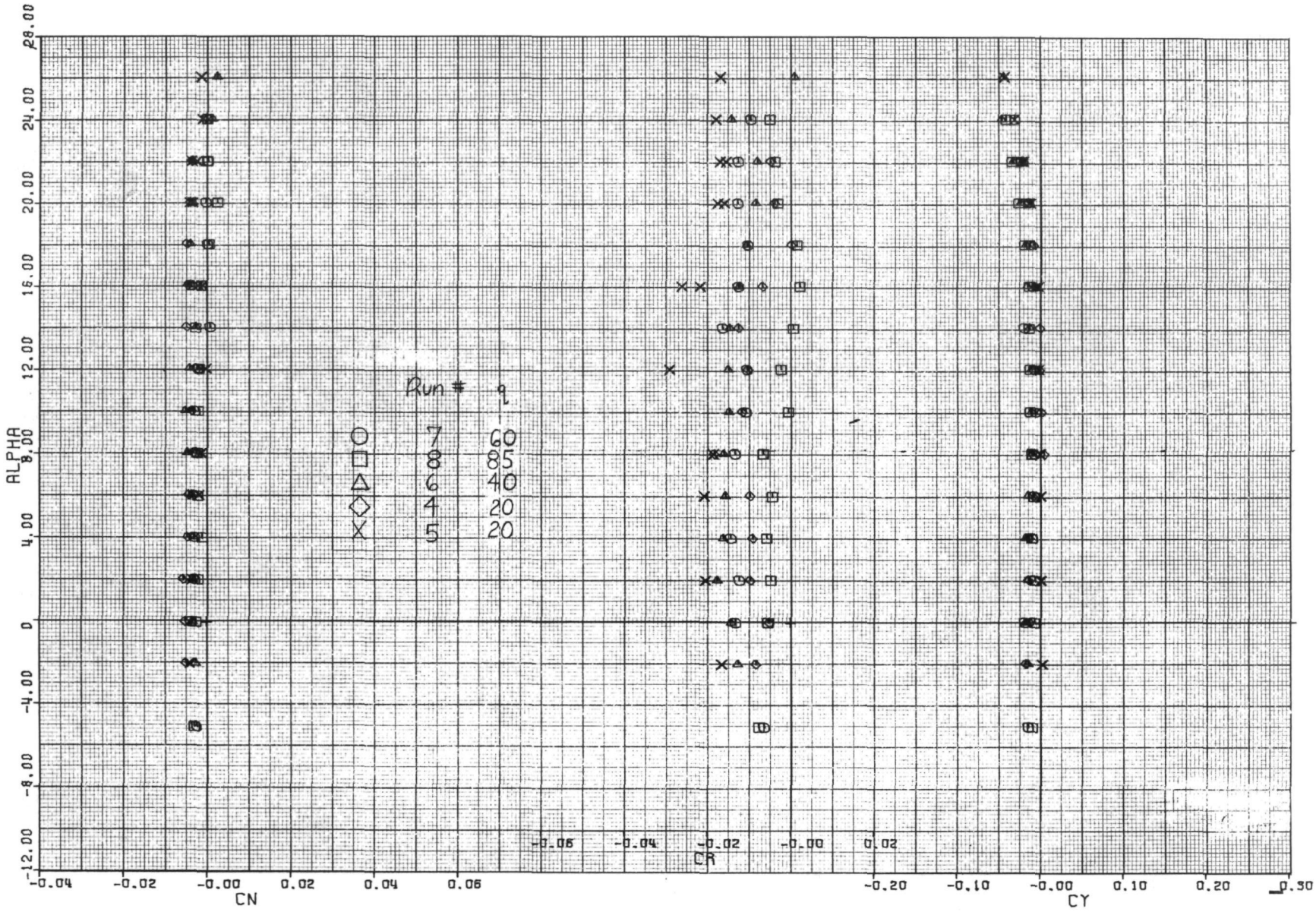
(d) Axial deployment sequence.

Figure 2.– Concluded.



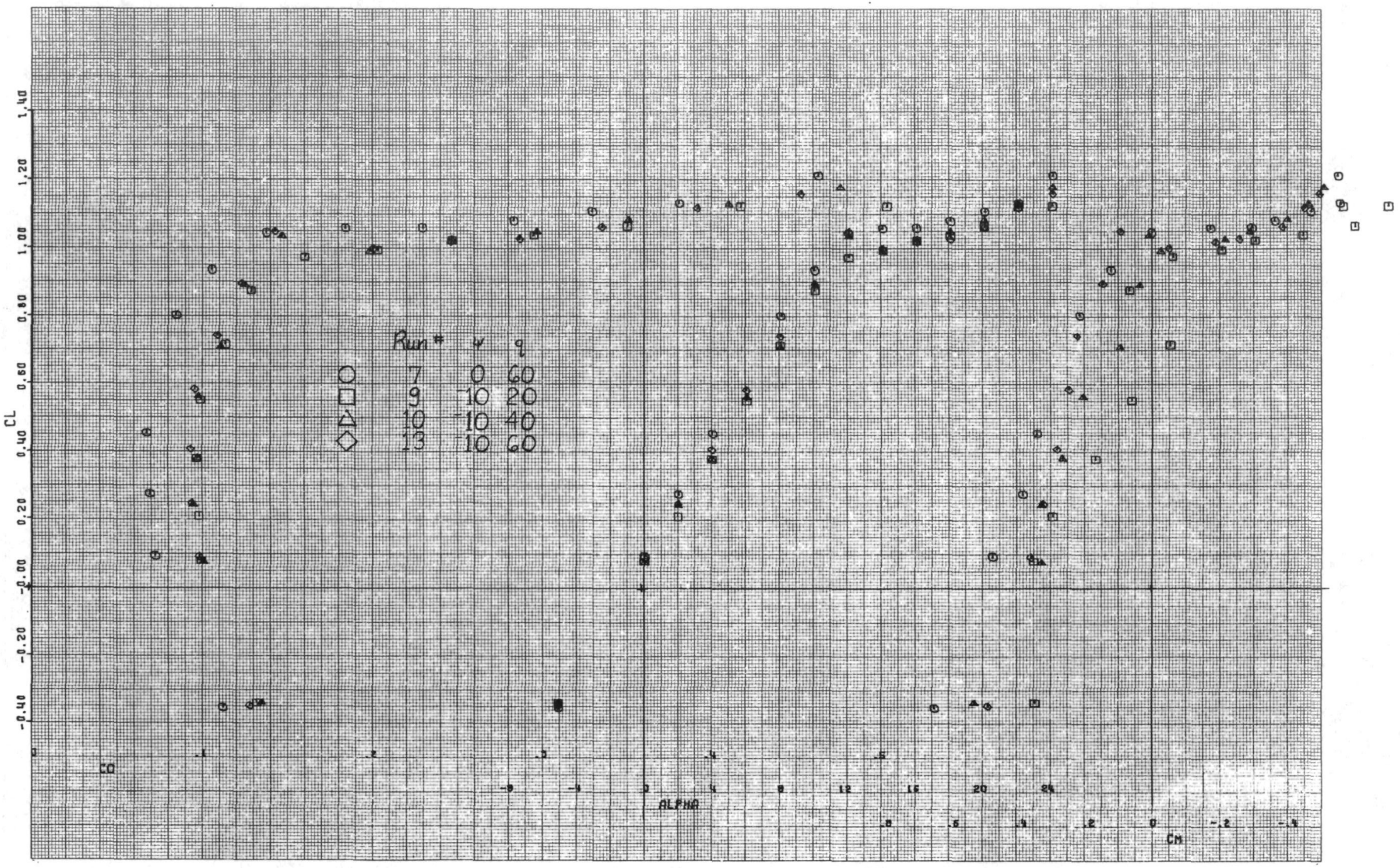
(a) Runs 7, 8, 6, 4, 5.

Figure 3.– Static aerodynamic data for configuration I.



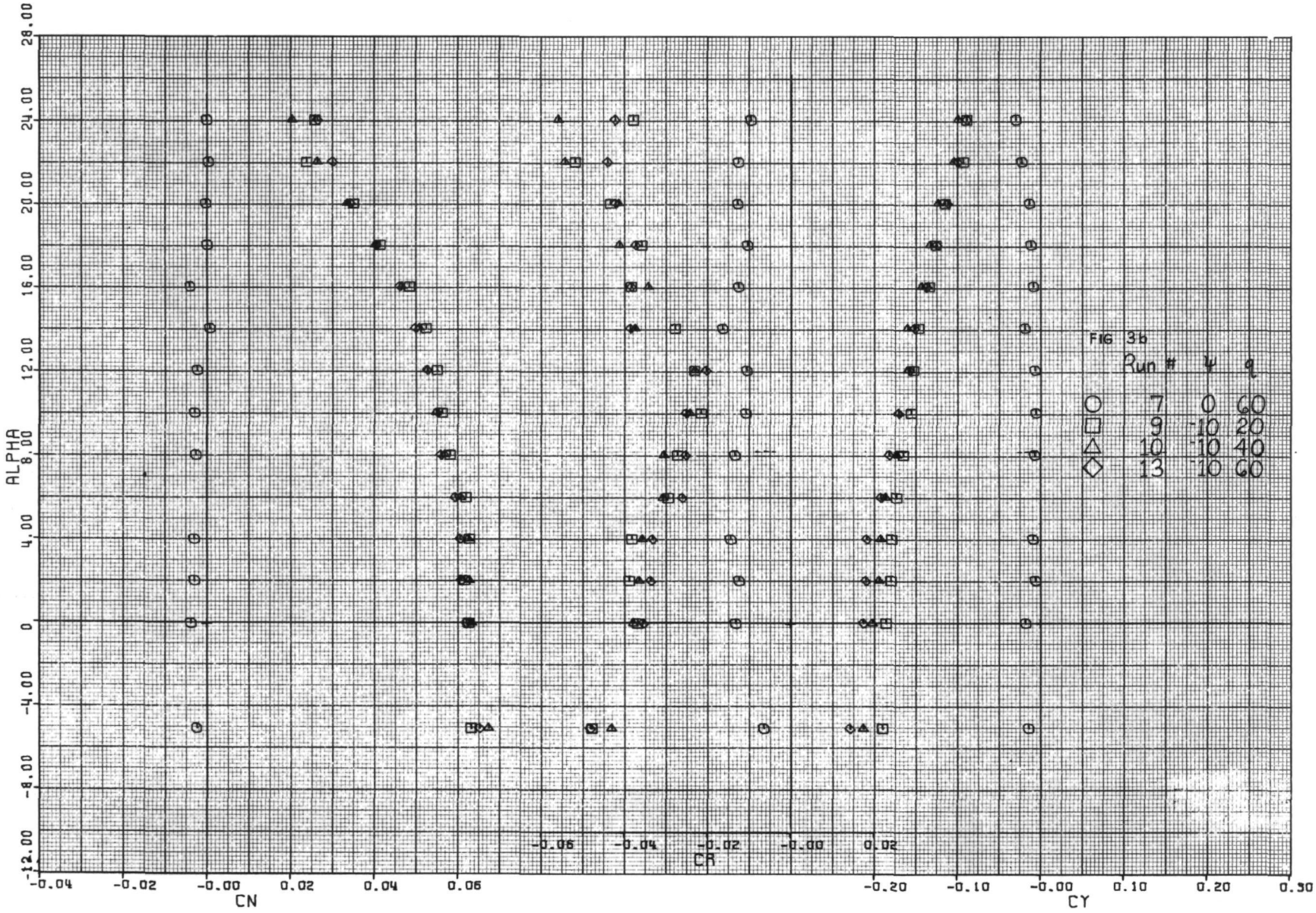
(a) Runs 7, 8, 6, 4, 5 – Concluded.

Figure 3.– Continued.



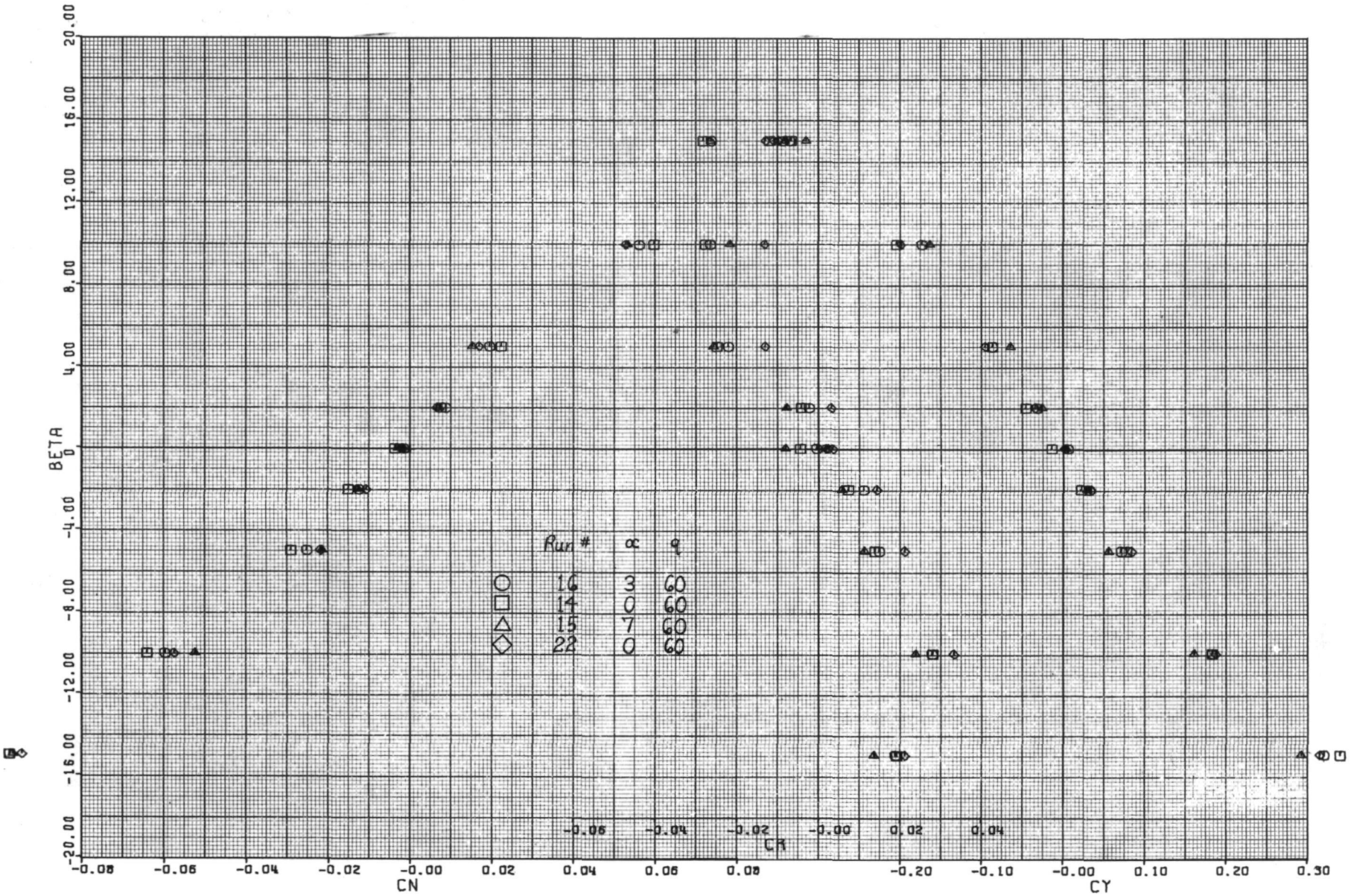
(b) Runs 7, 9, 10, 13.

Figure 3.– Continued.



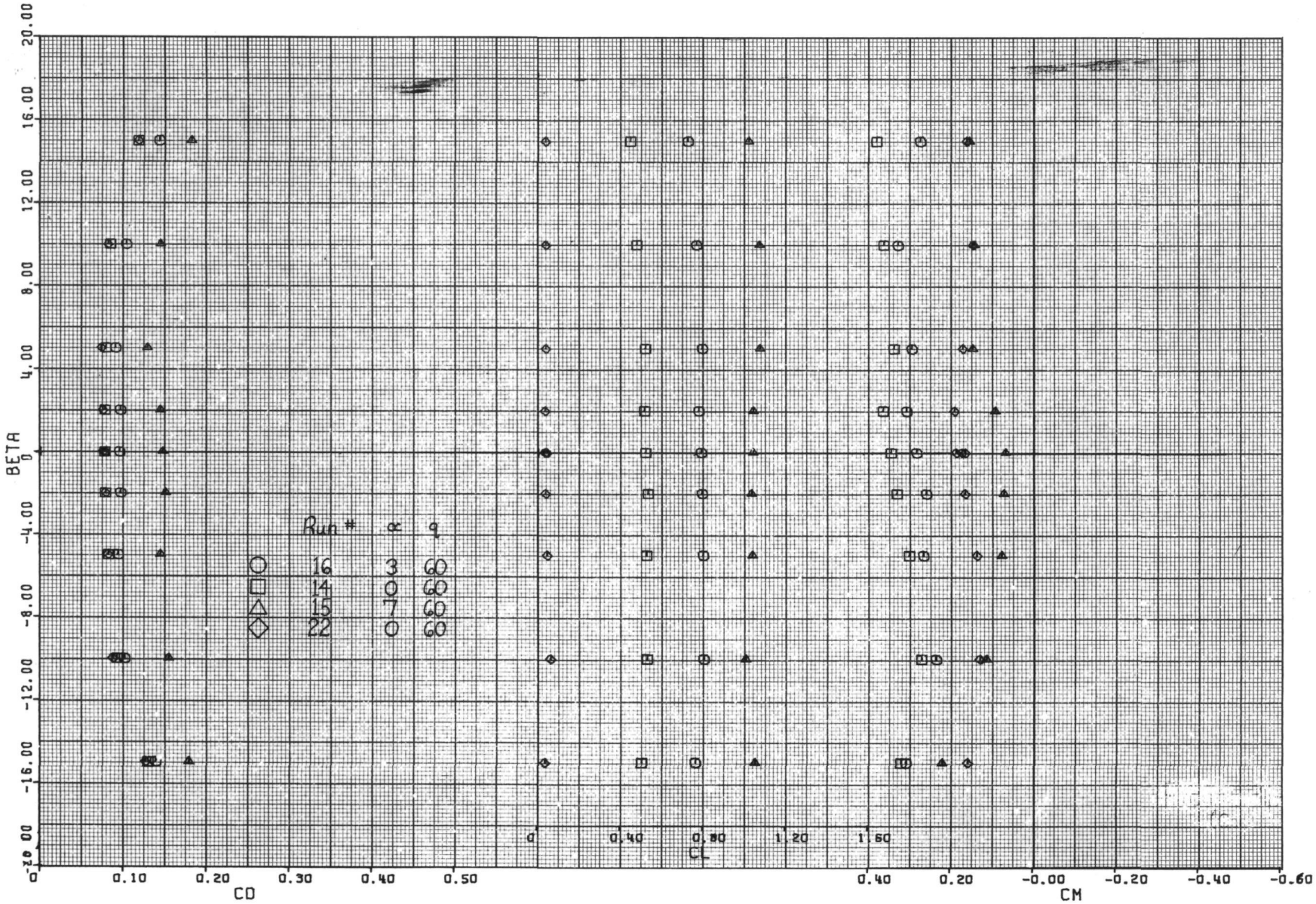
(b) Runs 7, 9, 10, 13 – Concluded.

Figure 3.– Continued.



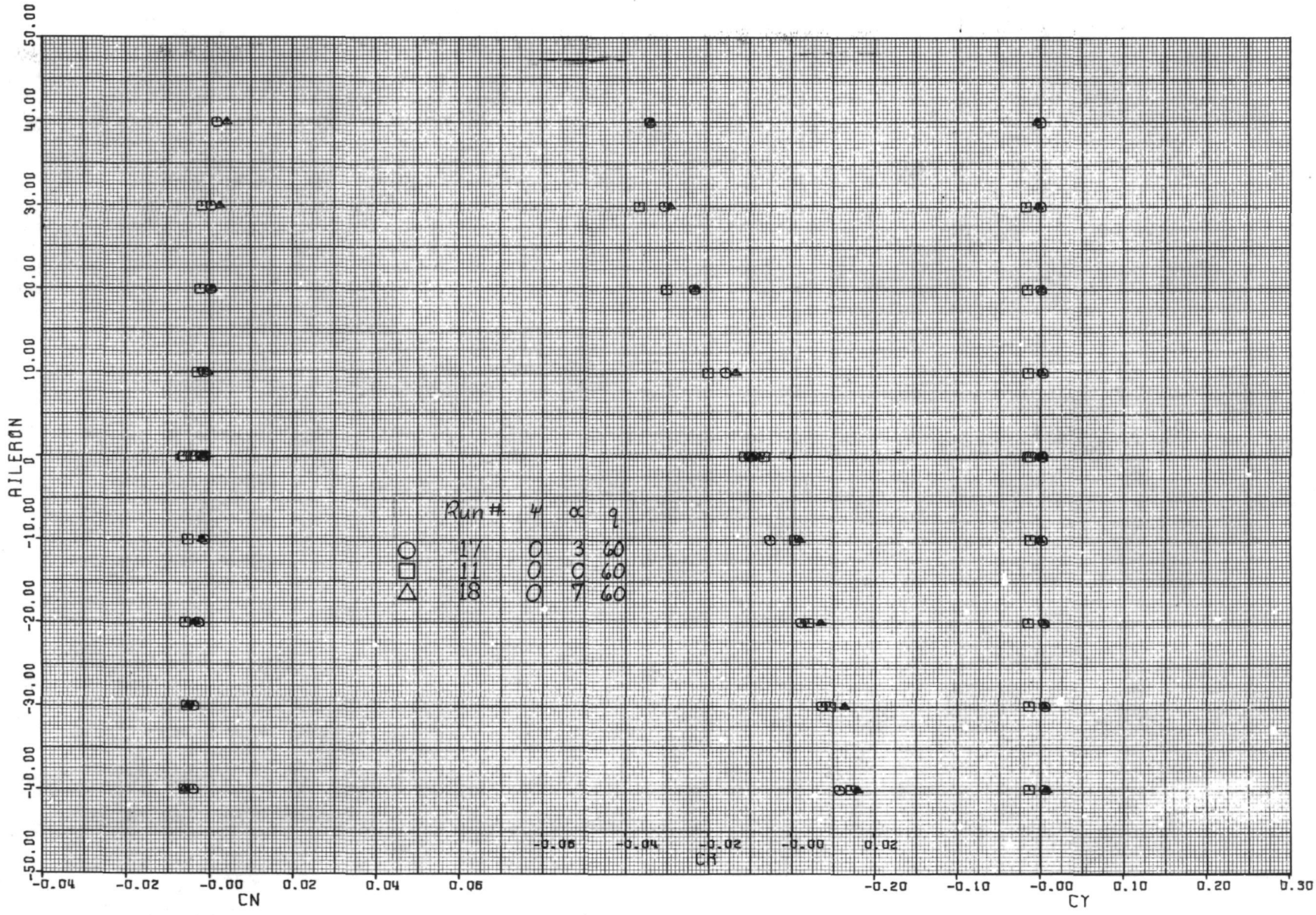
(c) Runs 16, 14, 15, 22.

Figure 3.– Continued.



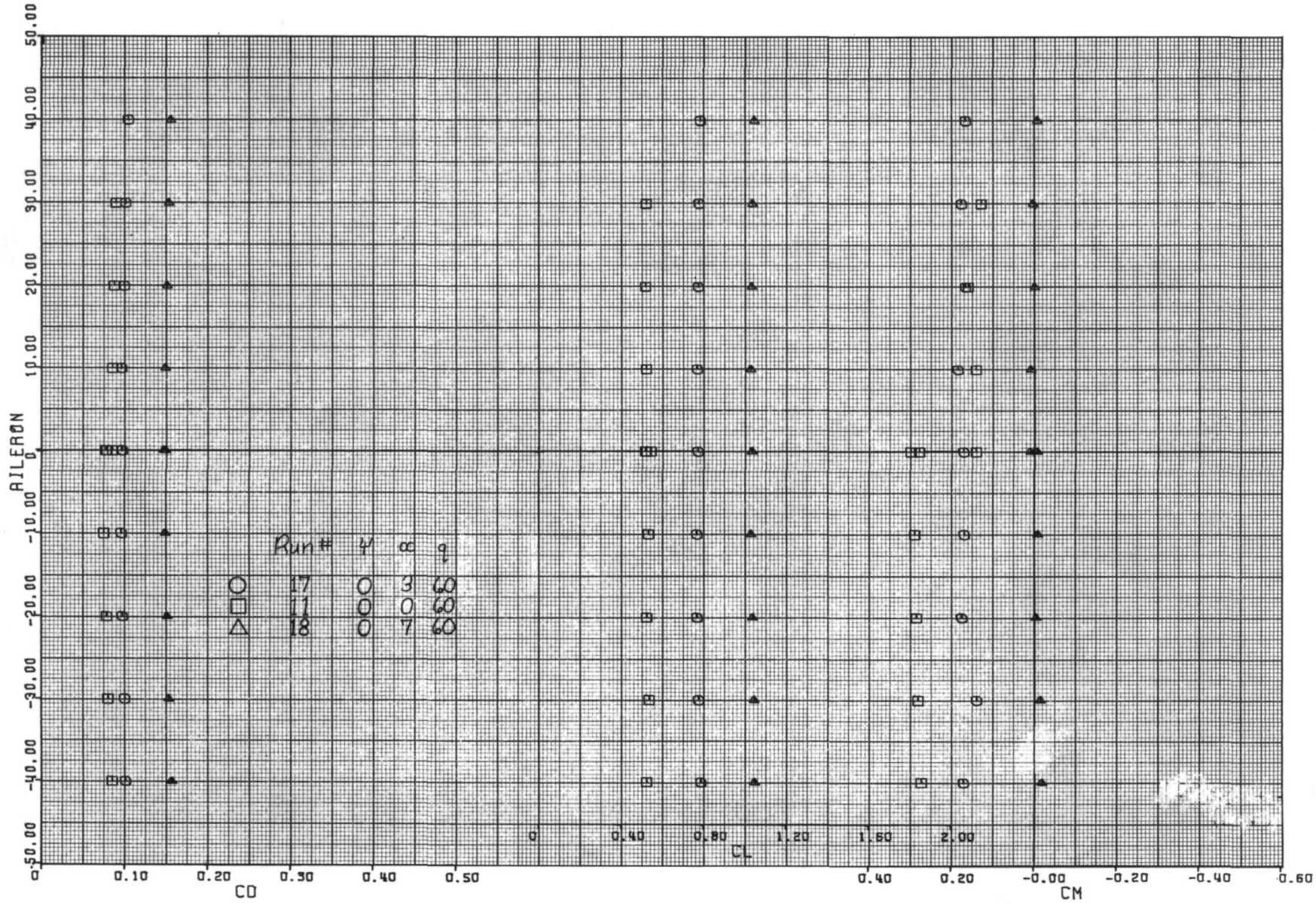
(c) Runs 16, 14, 15, 22 – Concluded.

Figure 3.– Continued.



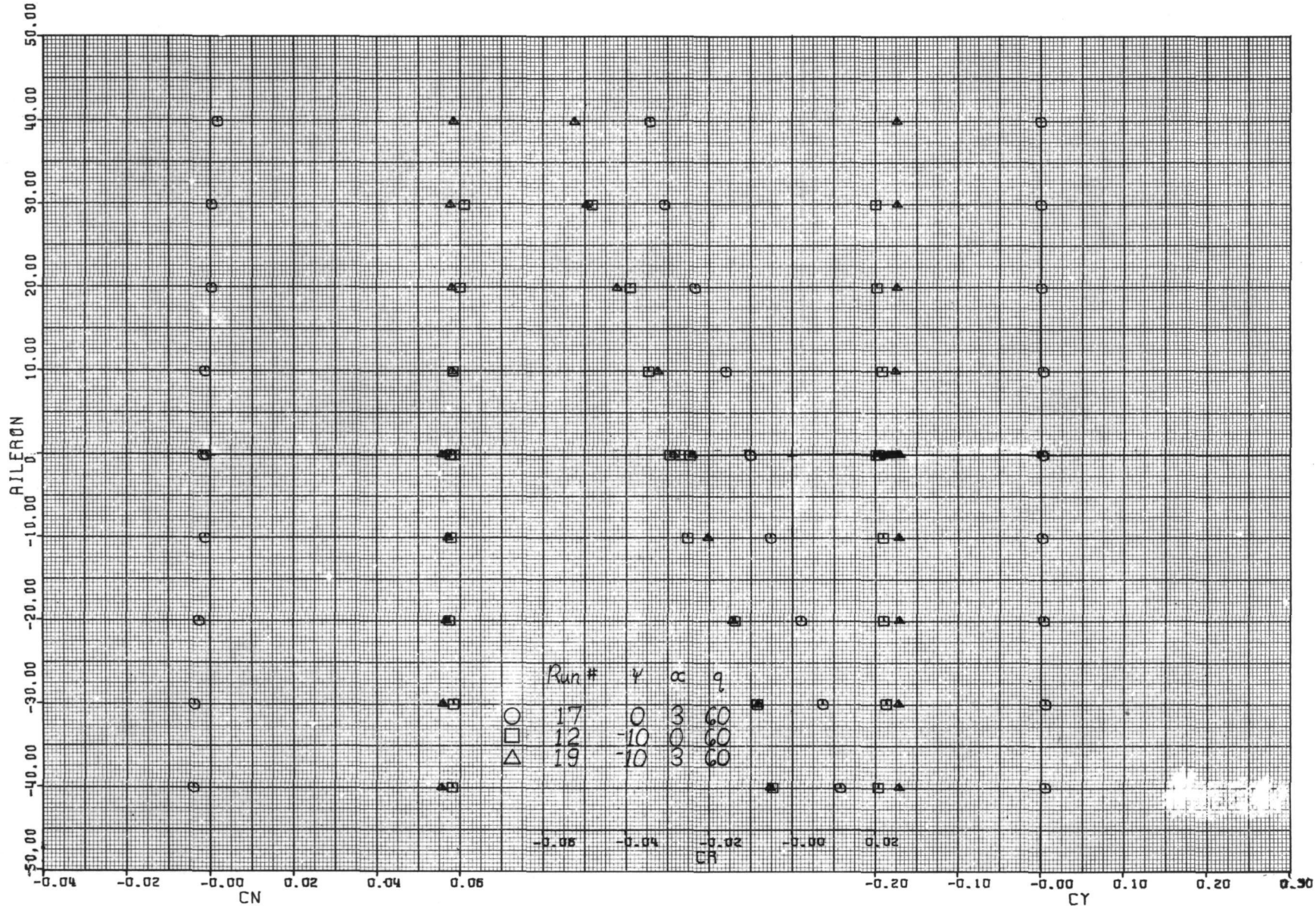
(d) Runs 17, 11, 18.

Figure 3. – Continued.



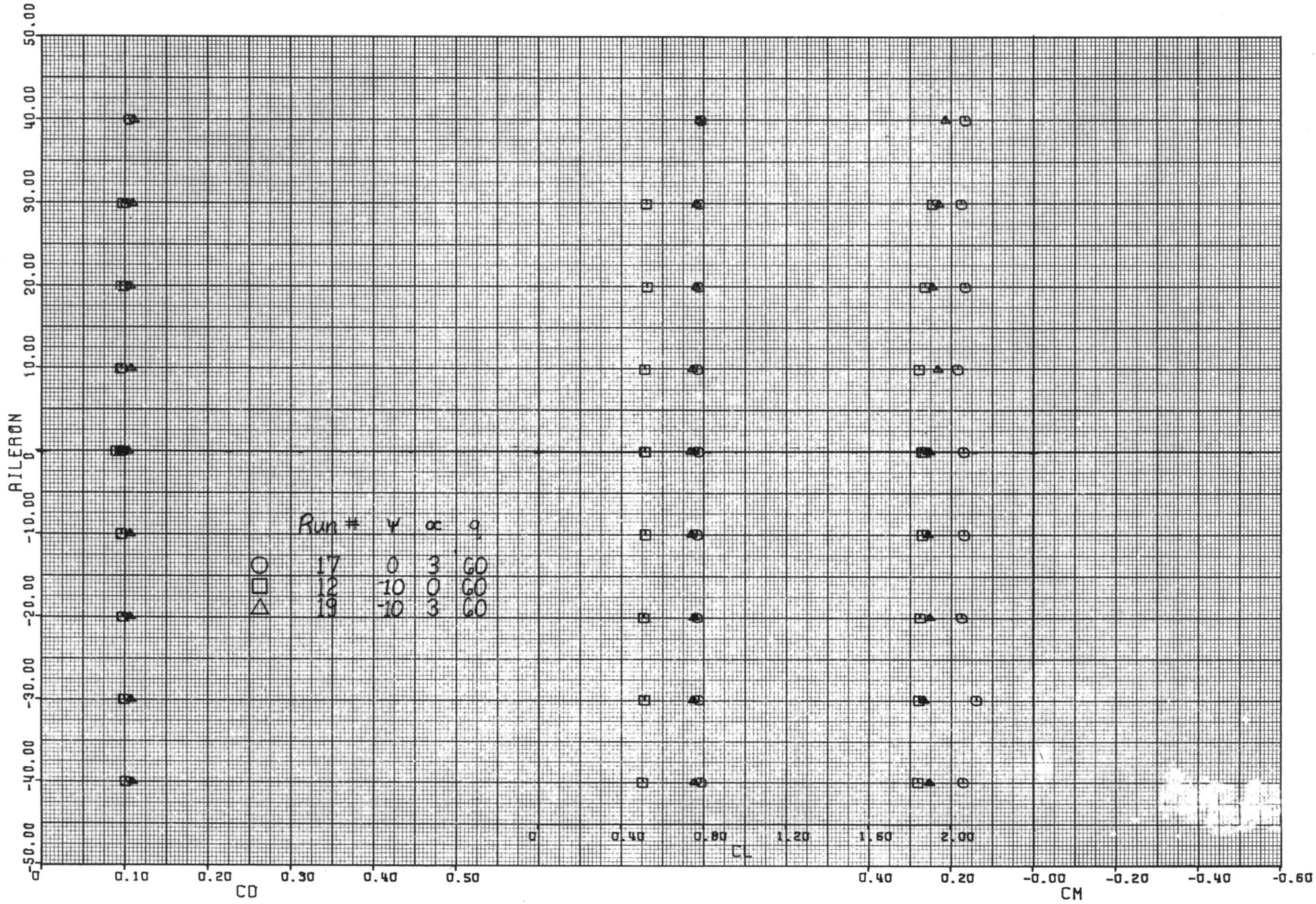
(d) Runs 17, 11, 18 – Concluded.

Figure 3.– Continued.



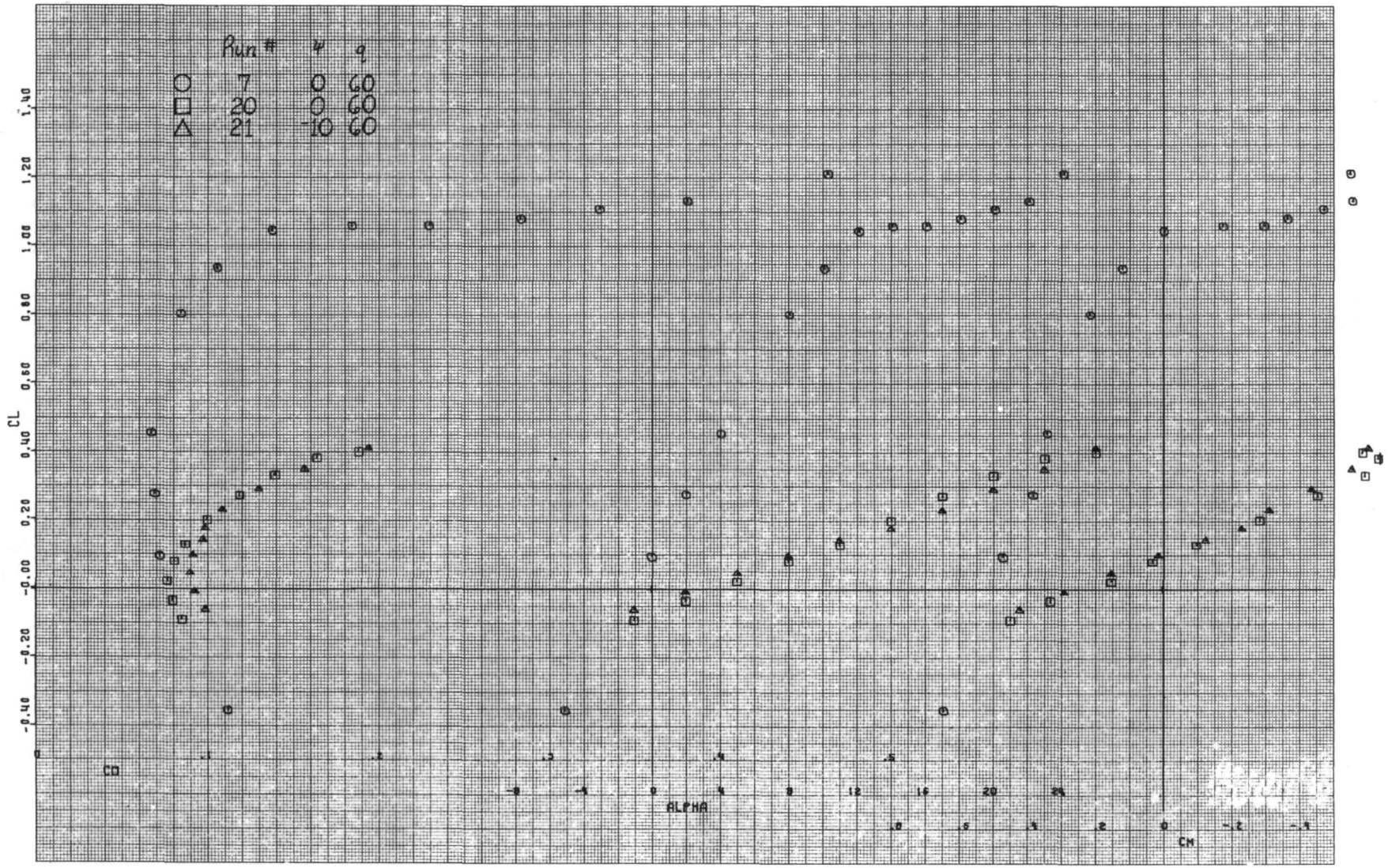
(e) Runs 17, 12, 19.

Figure 3.– Continued.



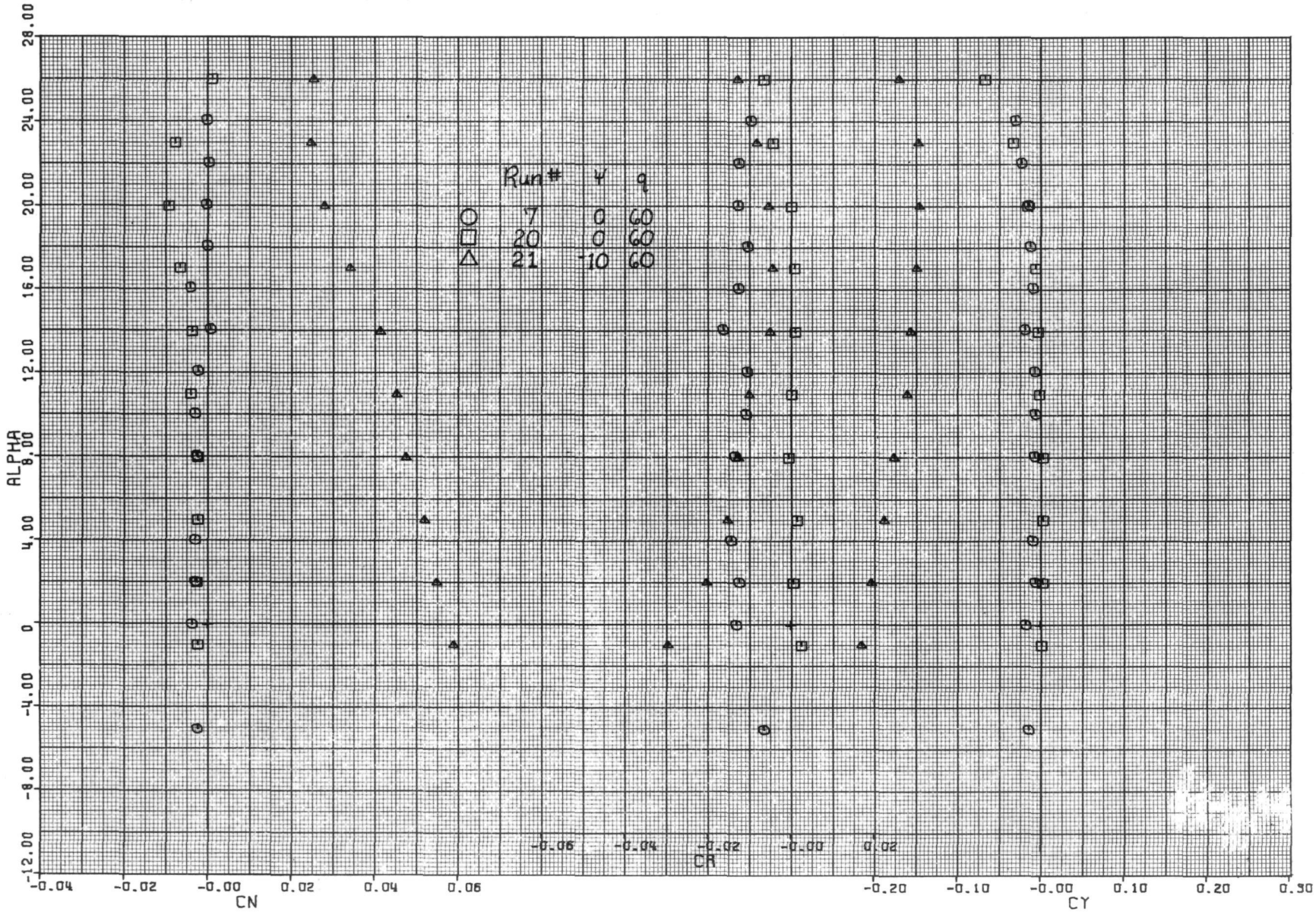
(e) Runs 17, 12, 19 – Concluded.

Figure 3.– Continued.



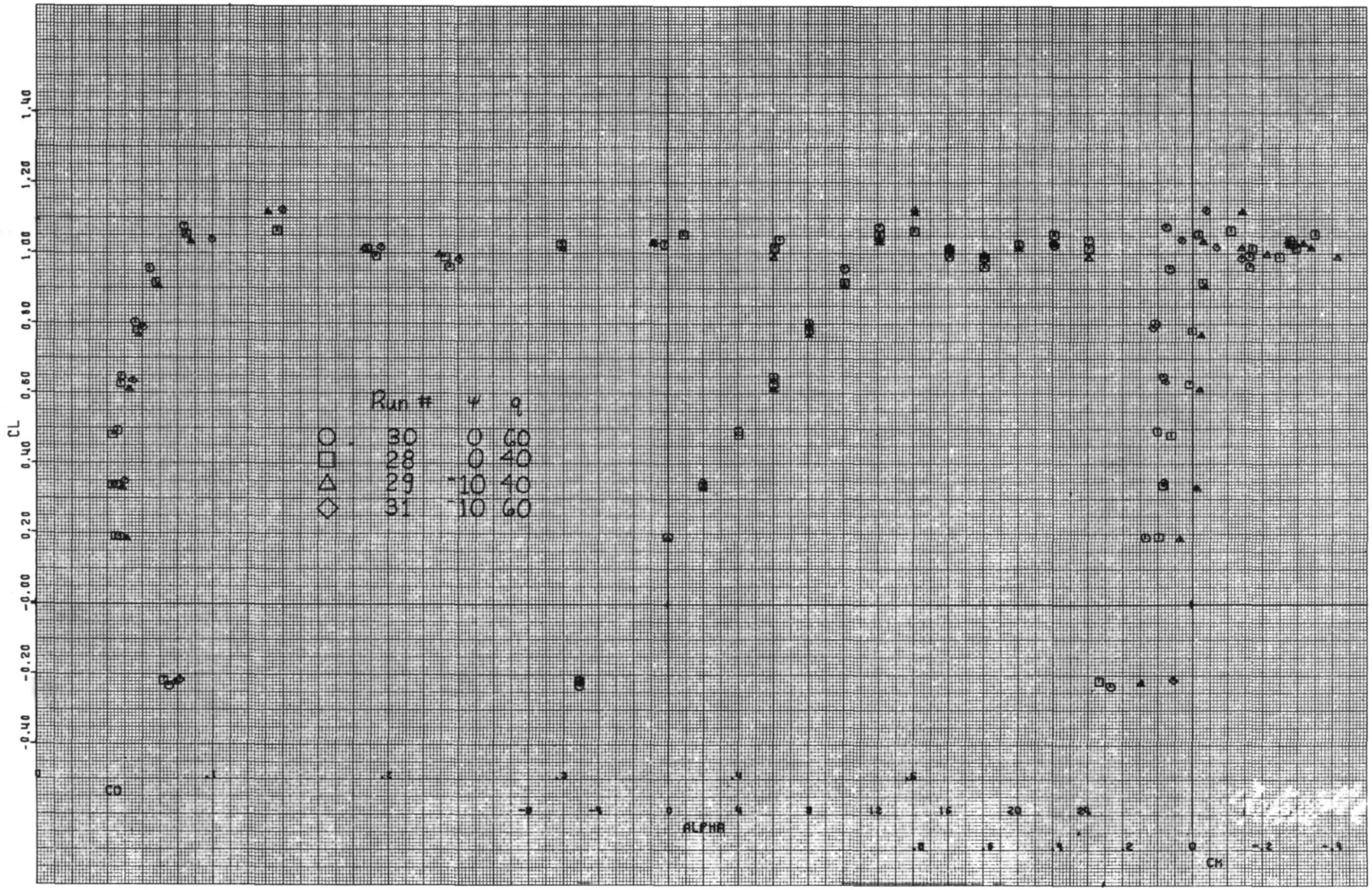
(f) Runs 7, 20, 21.

Figure 3.– Continued.



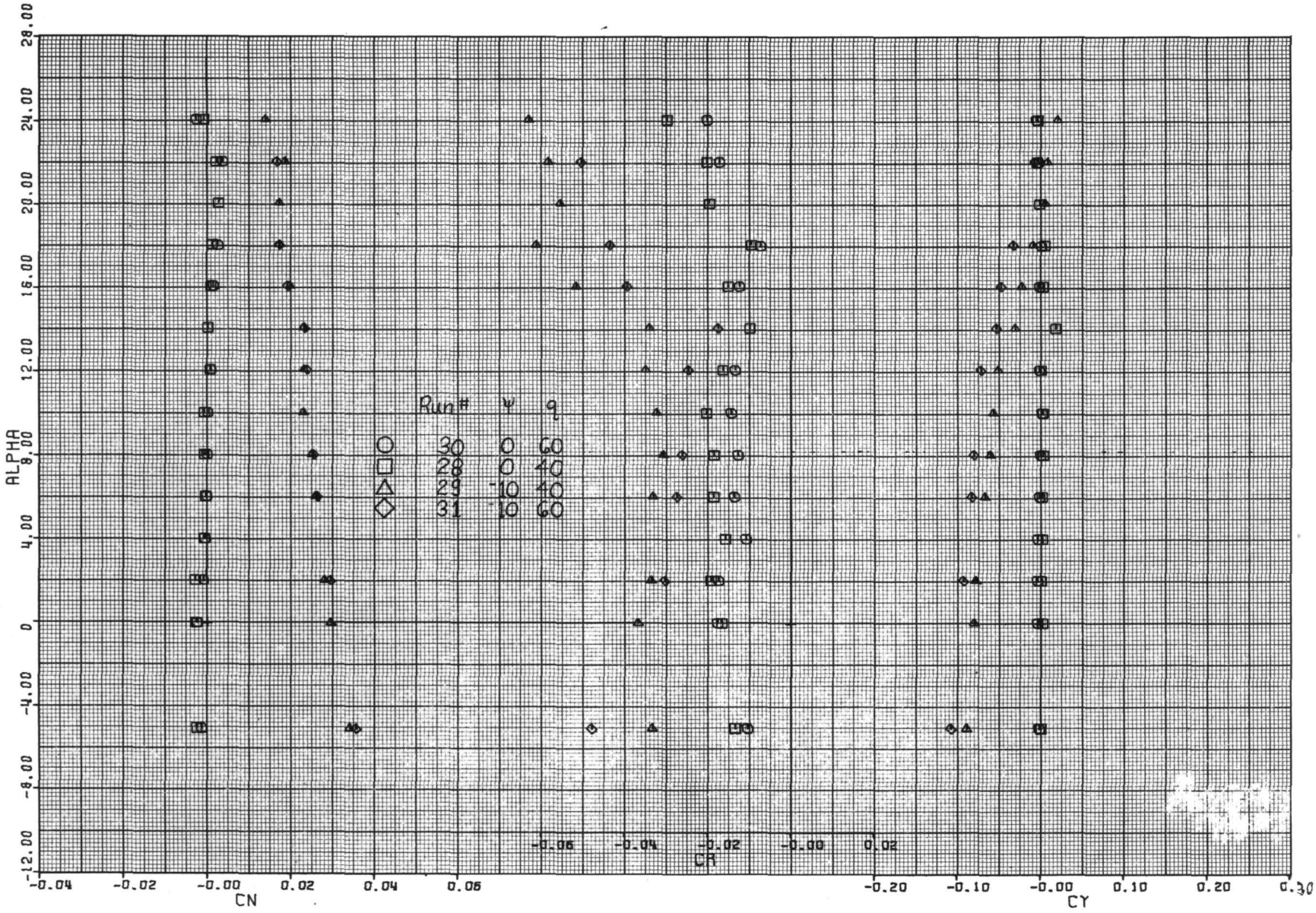
(f) Runs 7, 20, 21 – Concluded.

Figure 3.– Concluded.



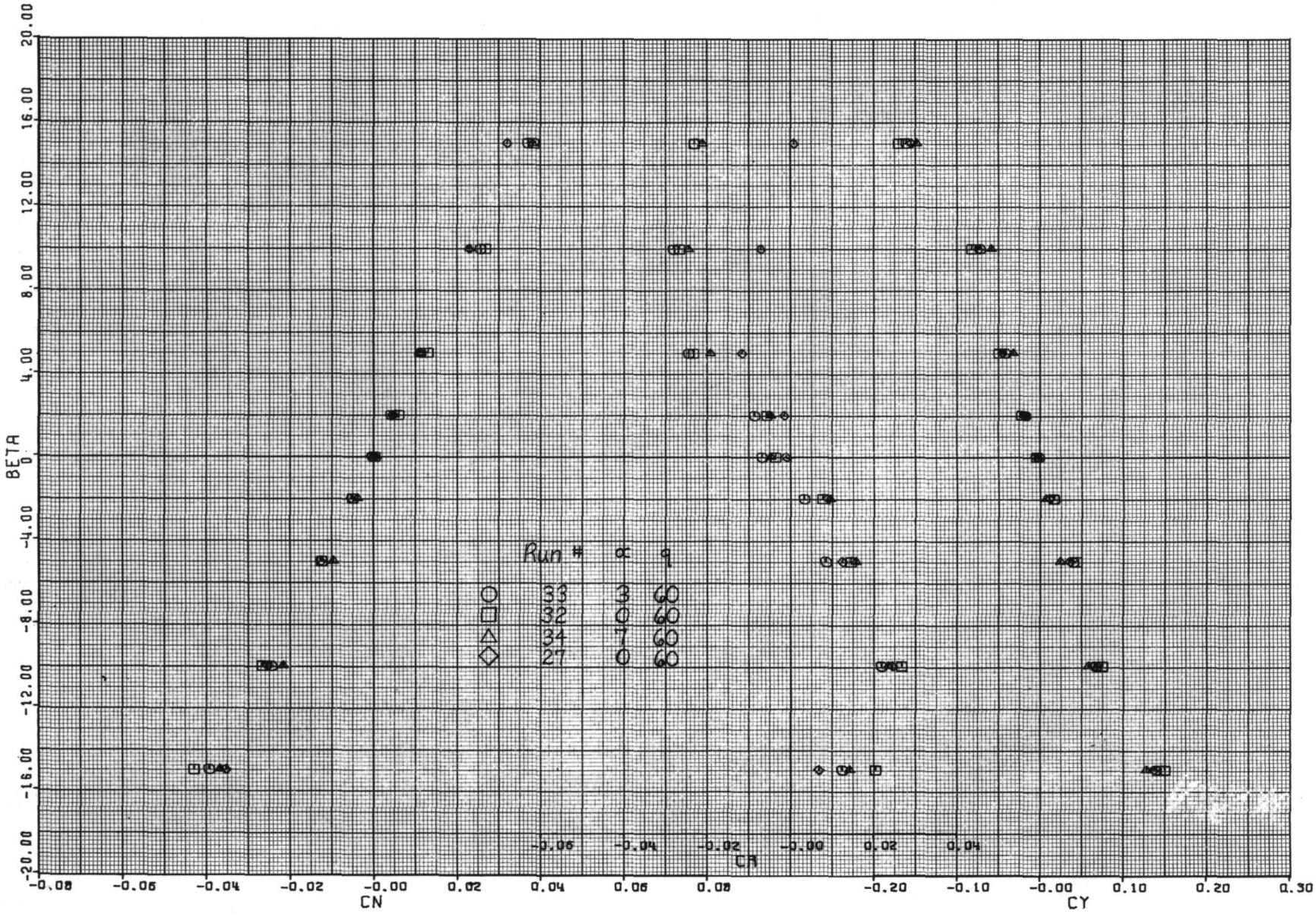
(a) Runs 30, 28, 29, 31.

Figure 4.– Static aerodynamic data for configuration II.



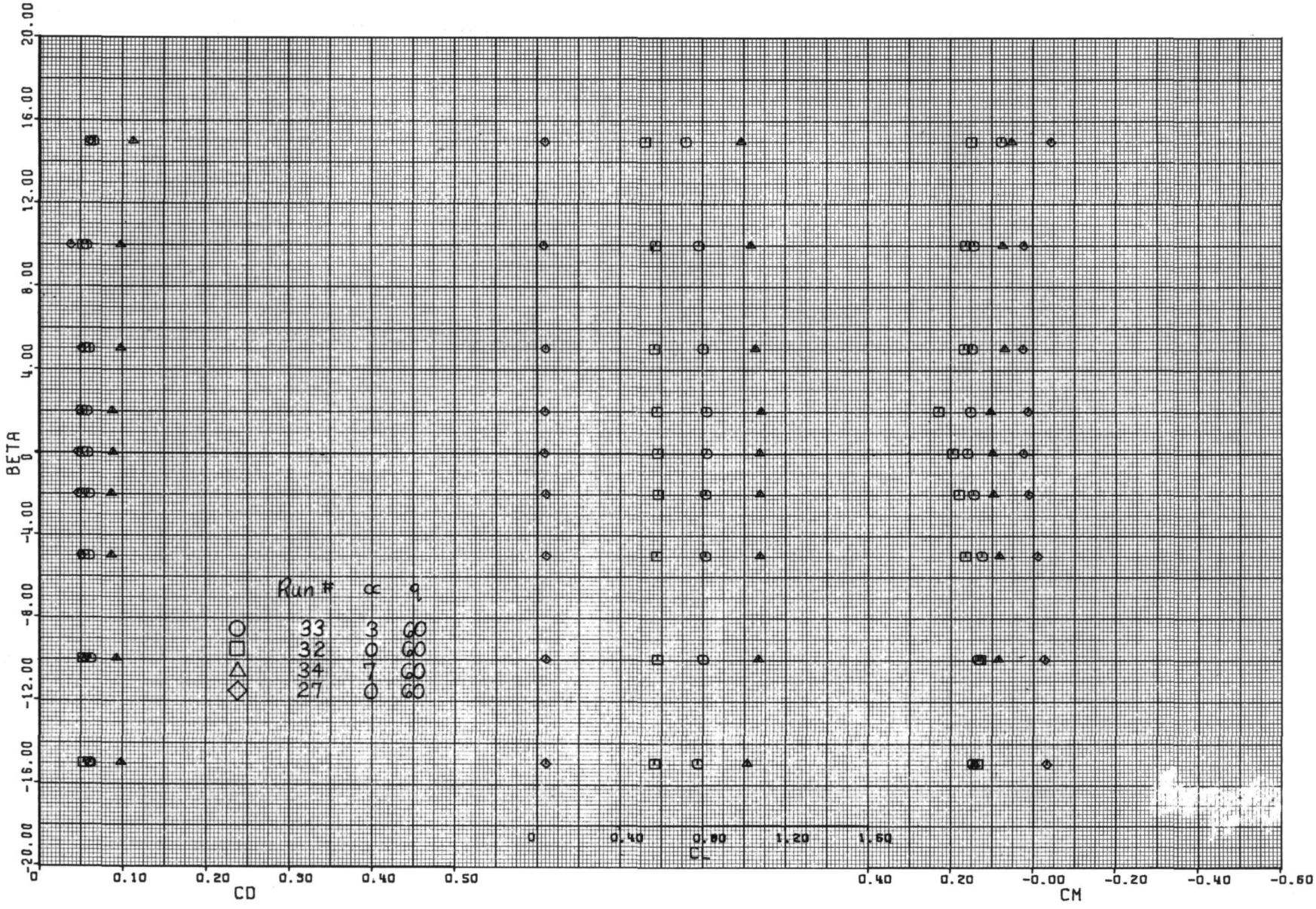
(a) Runs 30, 28, 29, 31 – Concluded.

Figure 4.– Continued.



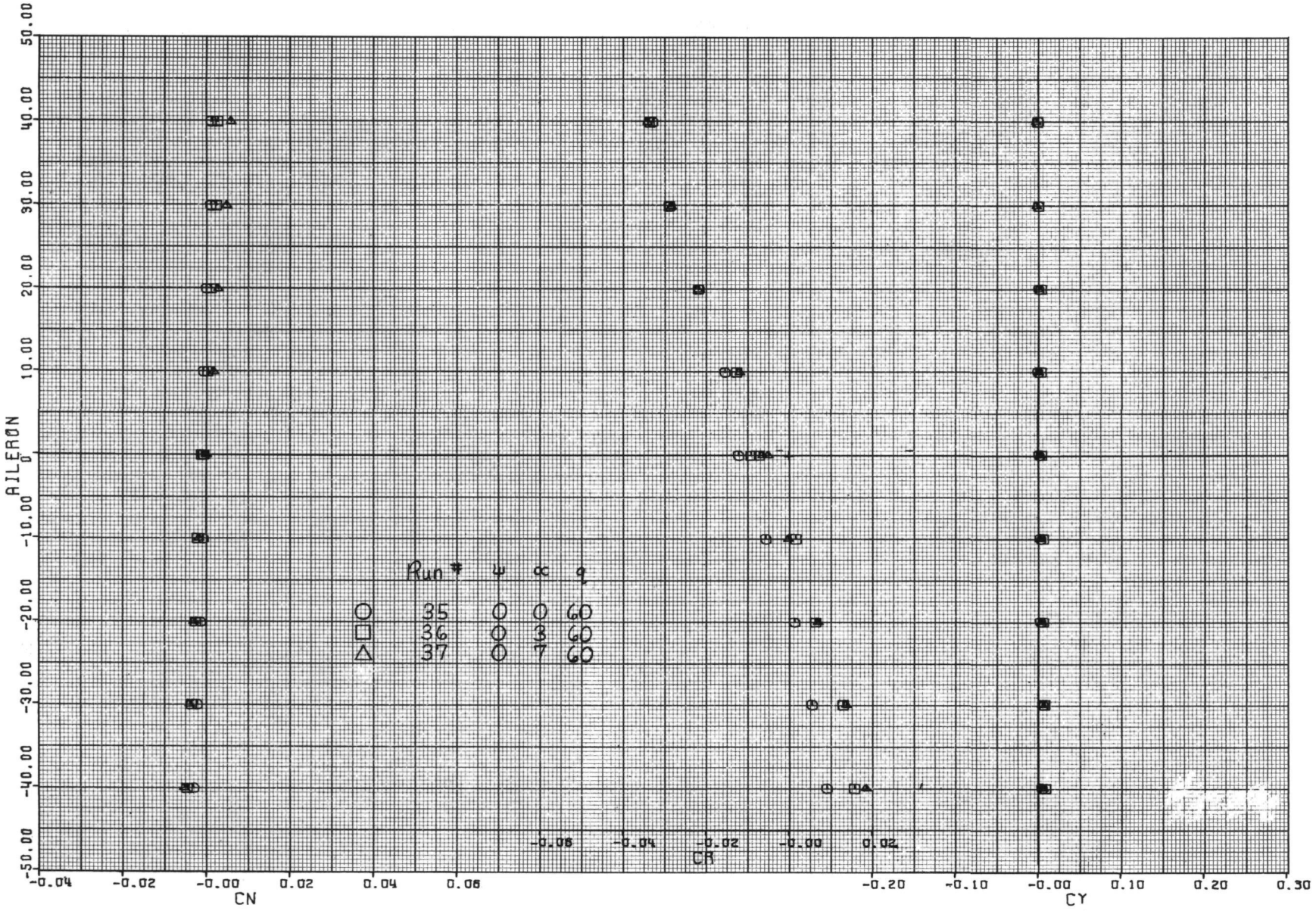
(b) Runs 33, 32, 34, 27.

Figure 4.– Continued.



(b) Runs 33, 32, 34, 27 – Concluded.

Figure 4.– Continued.



(c) Runs 35, 36, 37.

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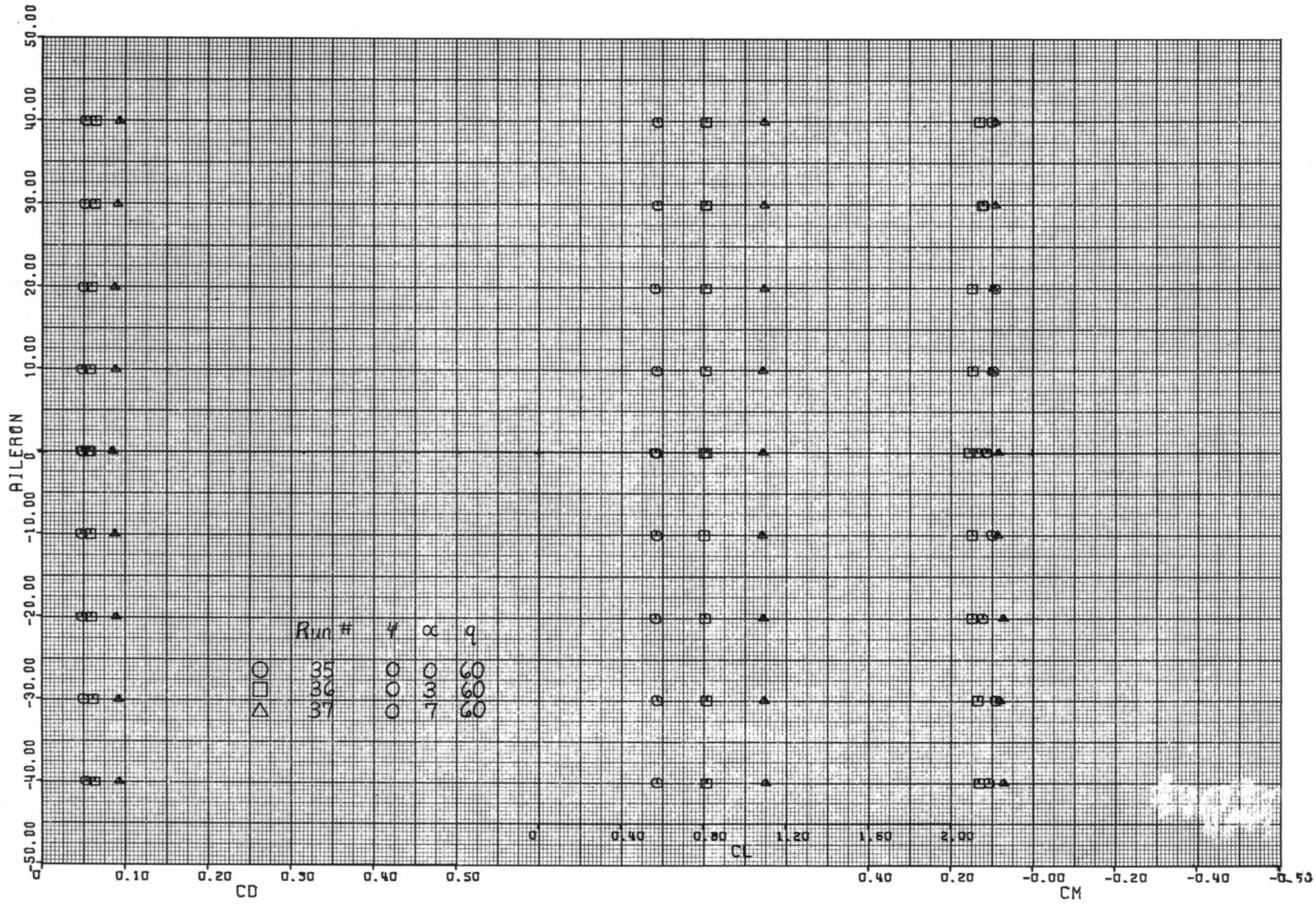
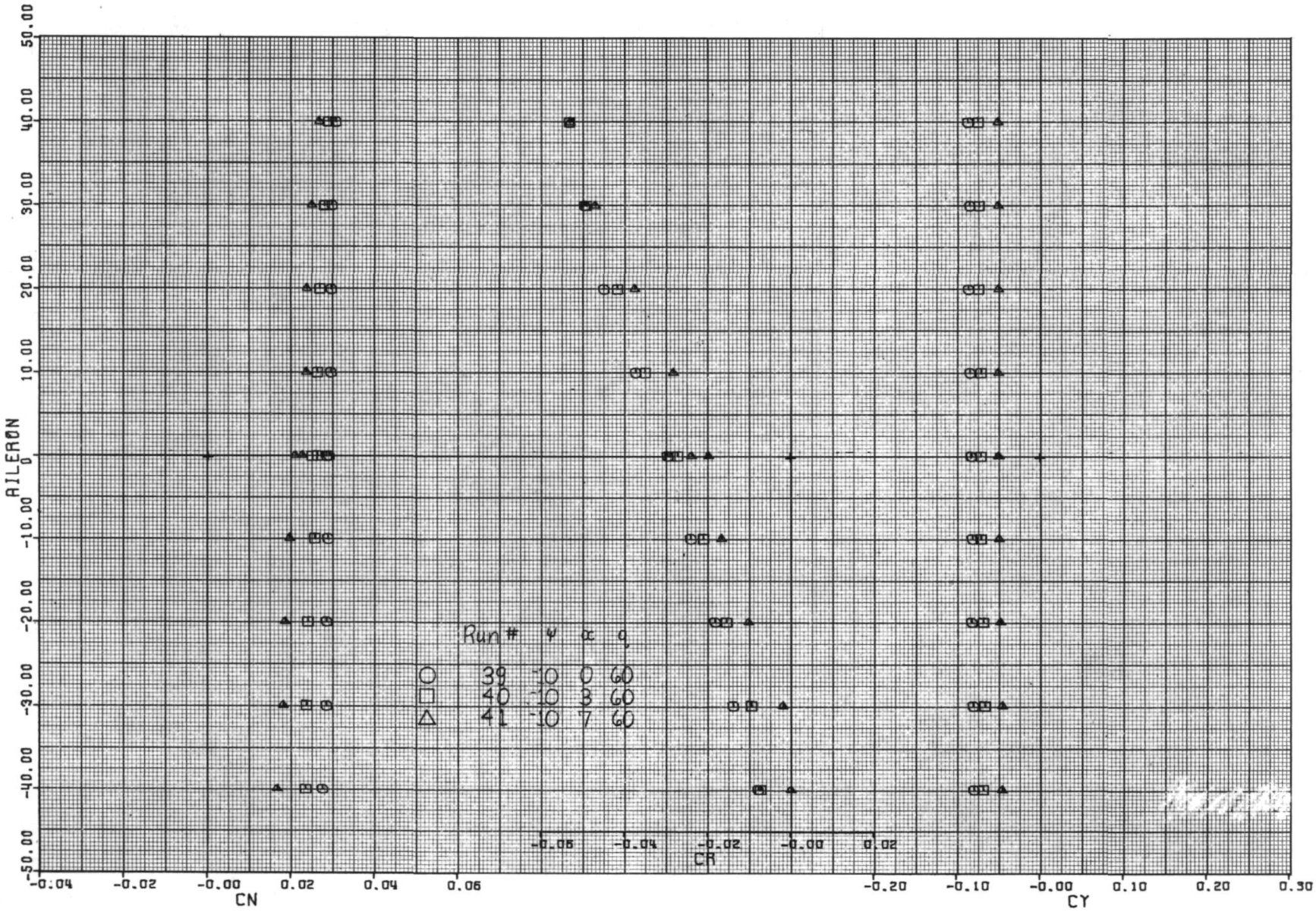


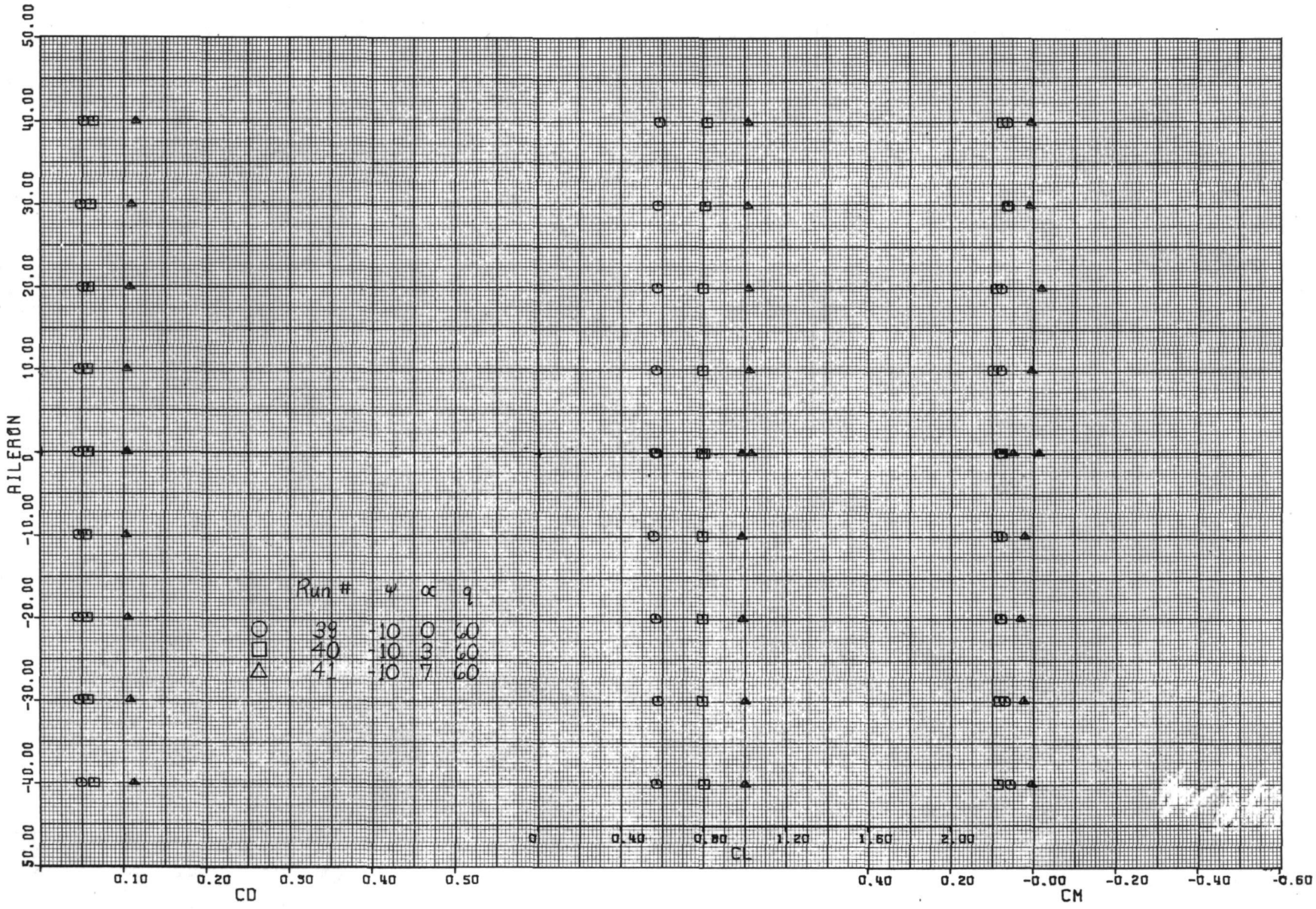
(c) Runs 35, 36, 37 – Concluded.

Figure 4.– Continued.



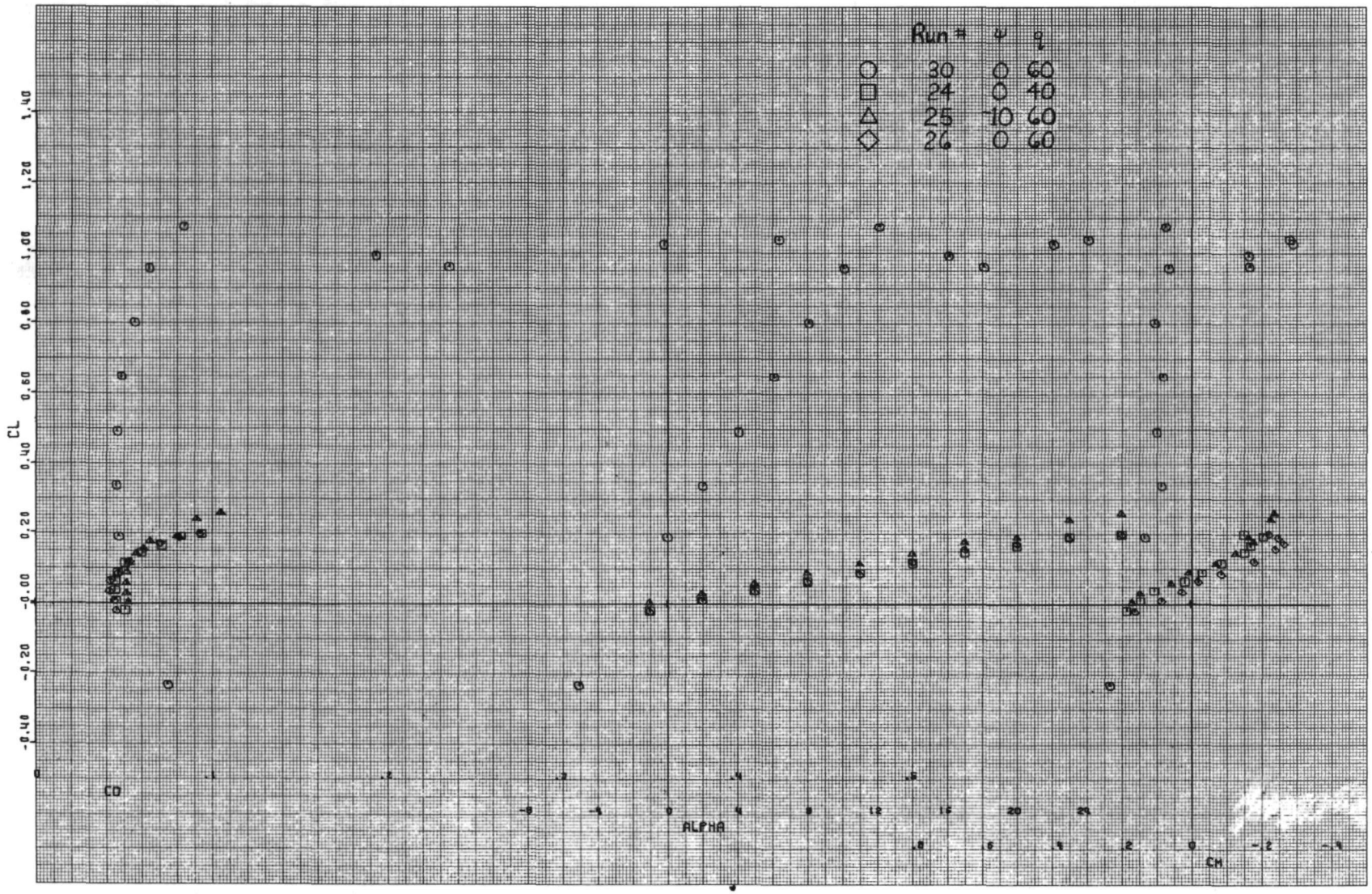
(d) Runs 39, 40, 41.

Figure 4.– Continued.



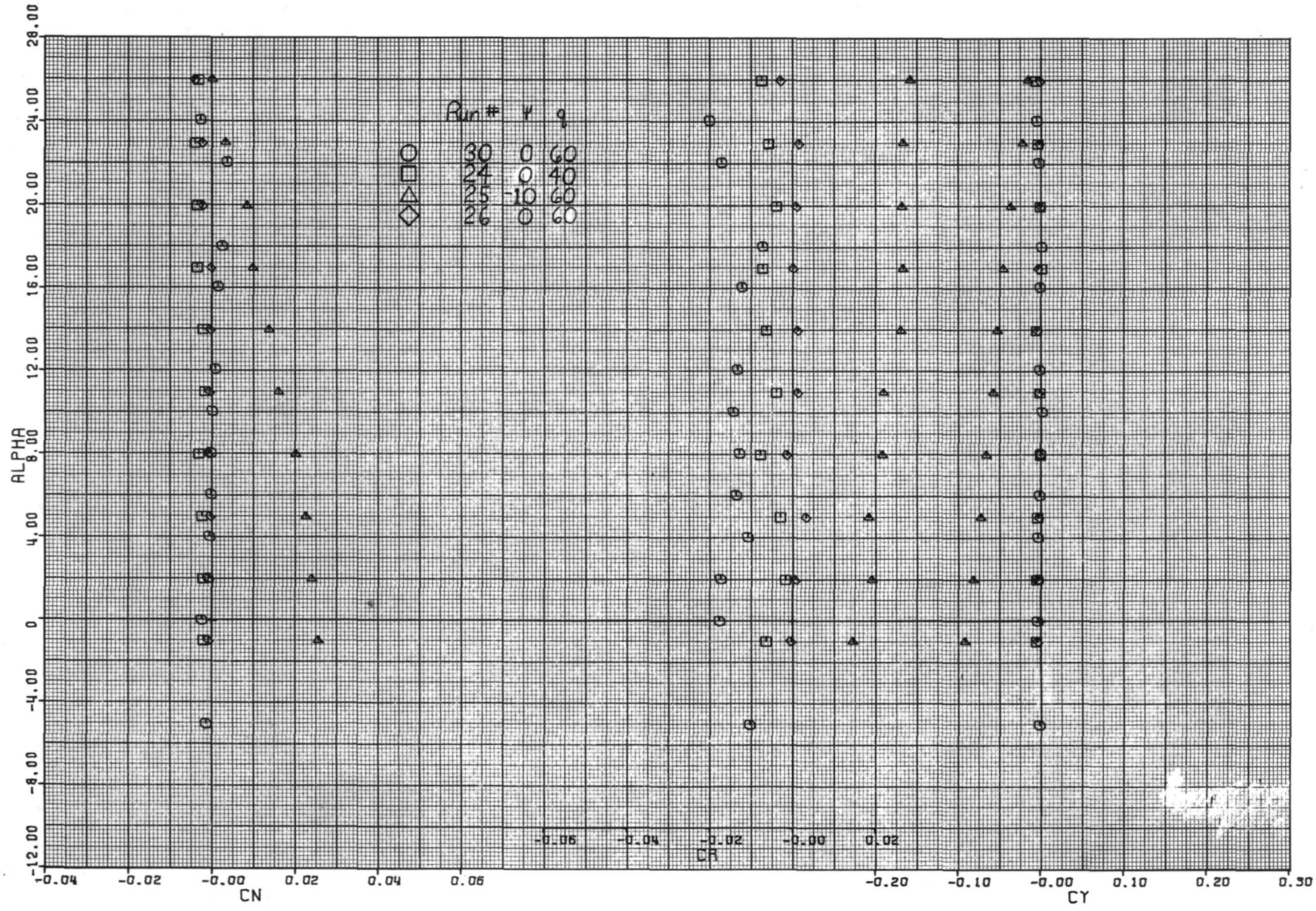
(d) Runs 39, 40, 41 – Concluded.

Figure 4.– Continued.



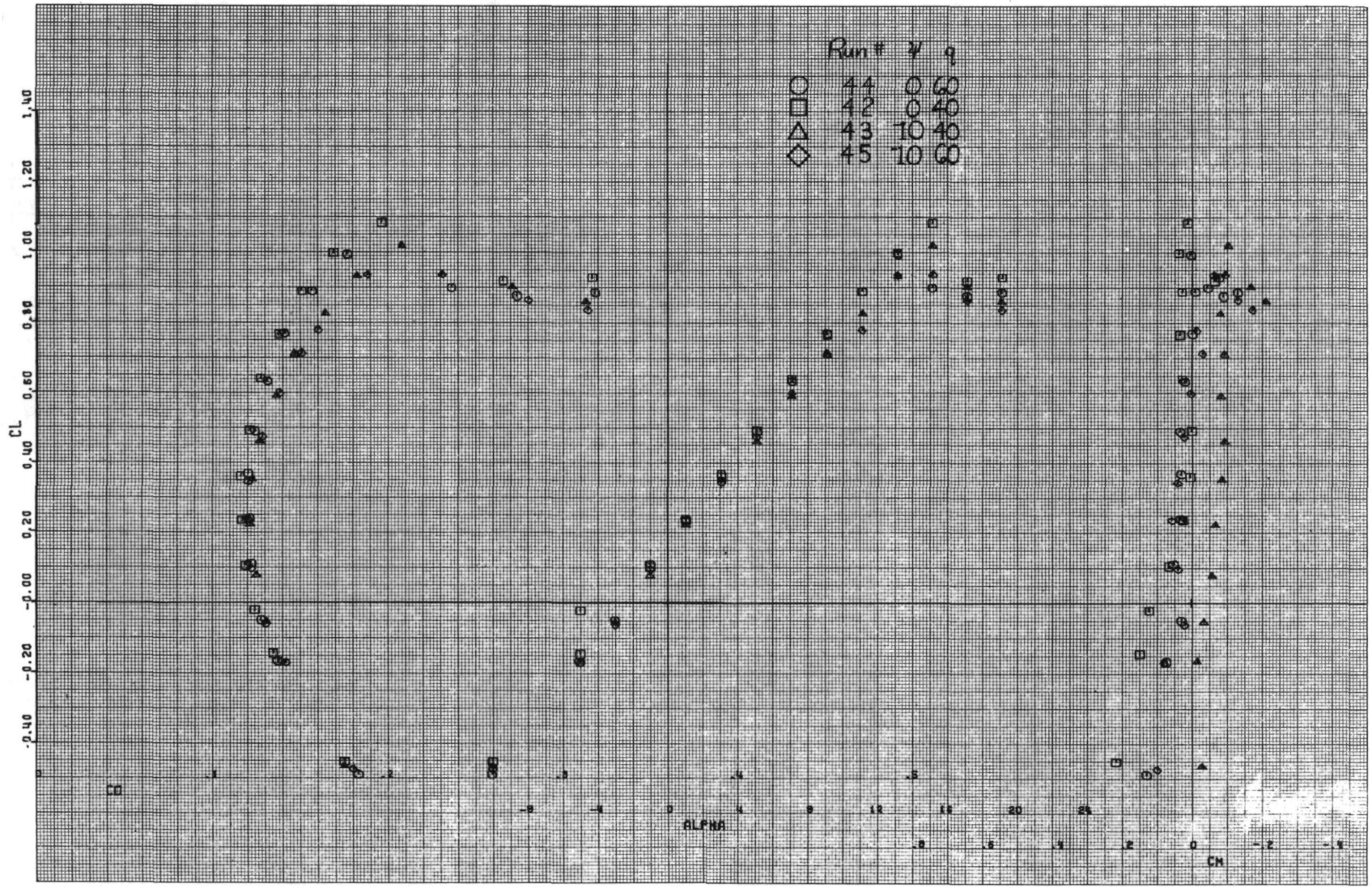
(e) Runs 30, 24, 25, 26.

Figure 4.– Continued.



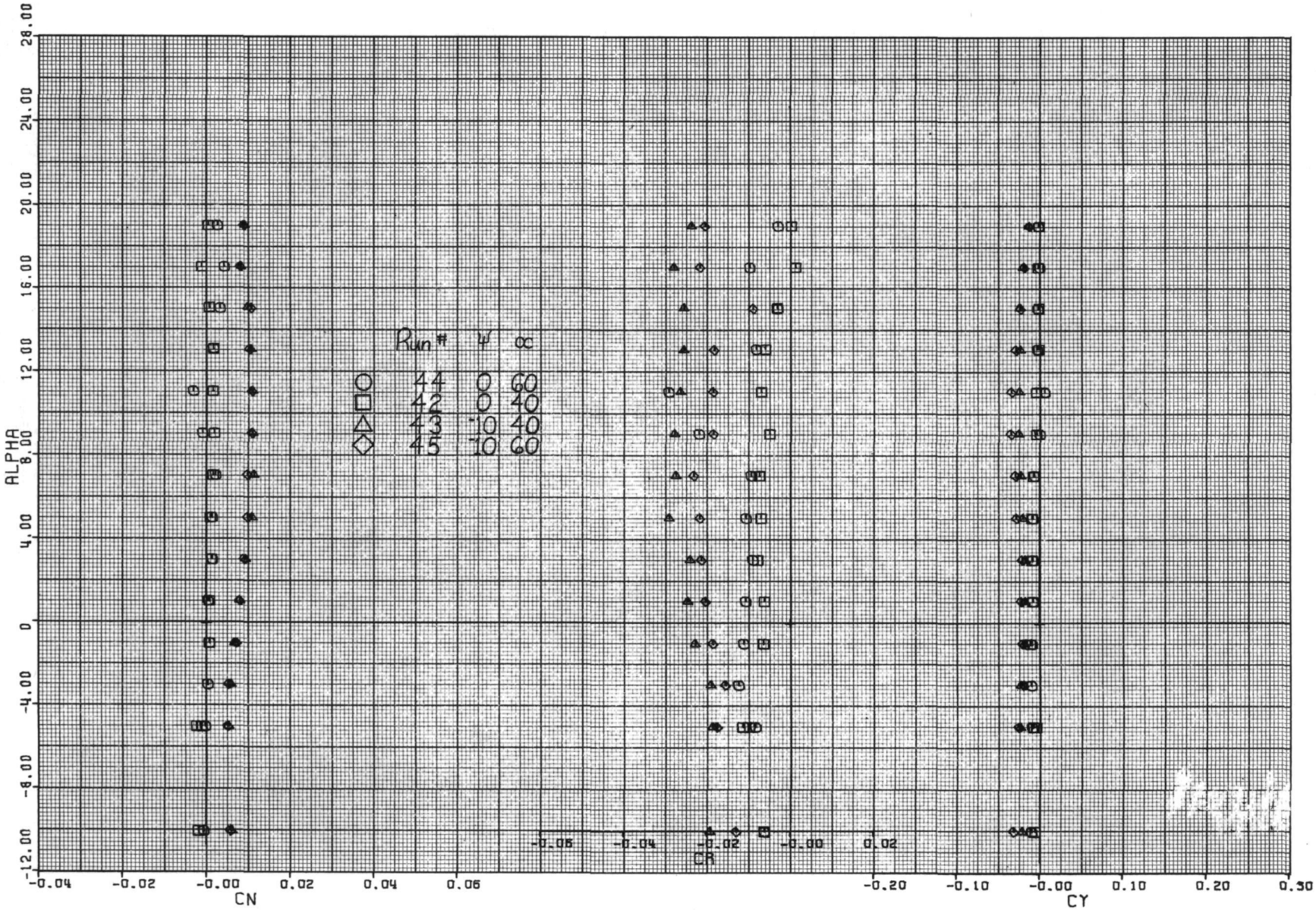
(e) Runs 30, 24, 25, 26 – Concluded.

Figure 4.– Concluded.



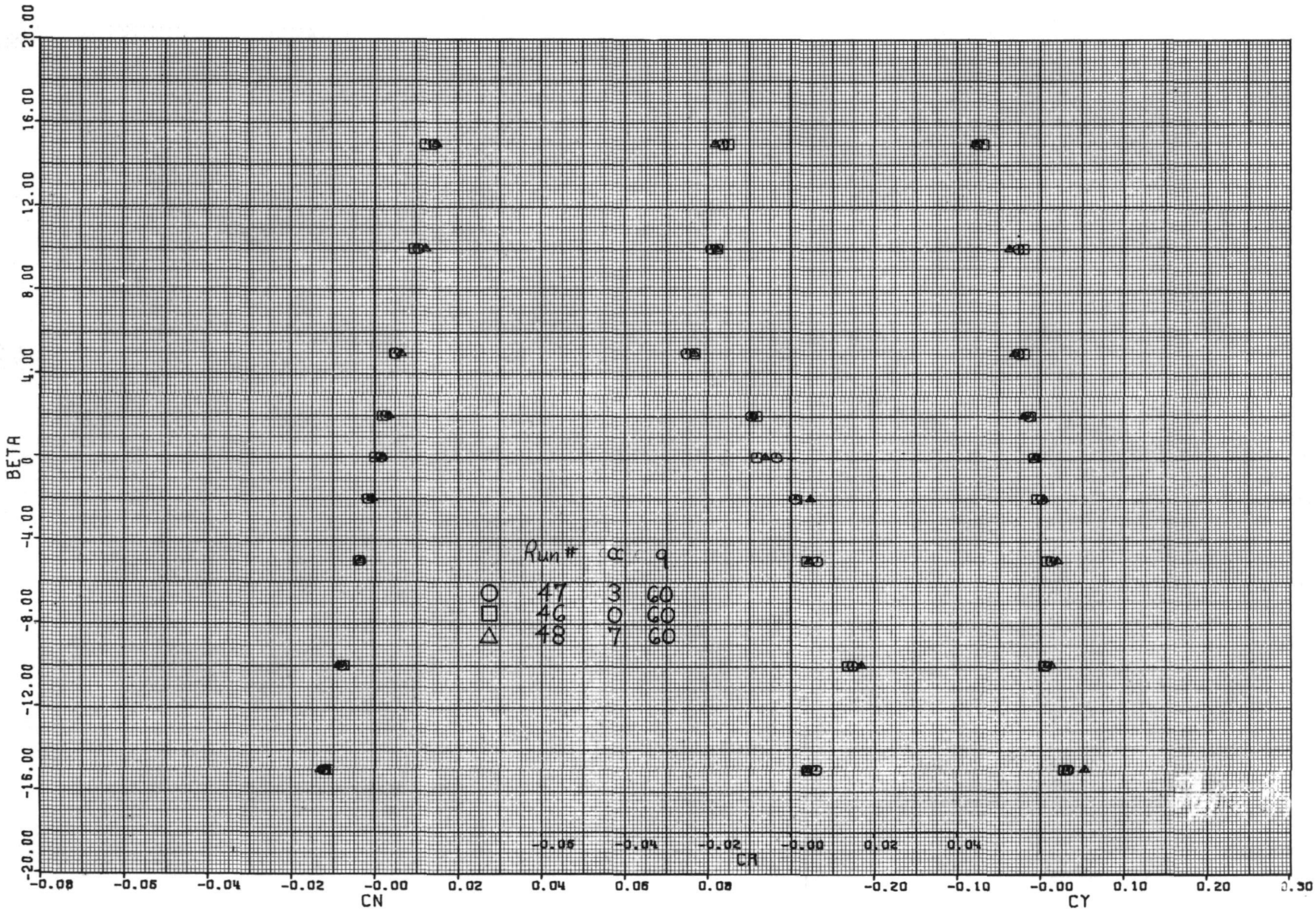
(a) Runs 44, 42, 43, 45.

Figure 5.– Static aerodynamic data for configuration III.



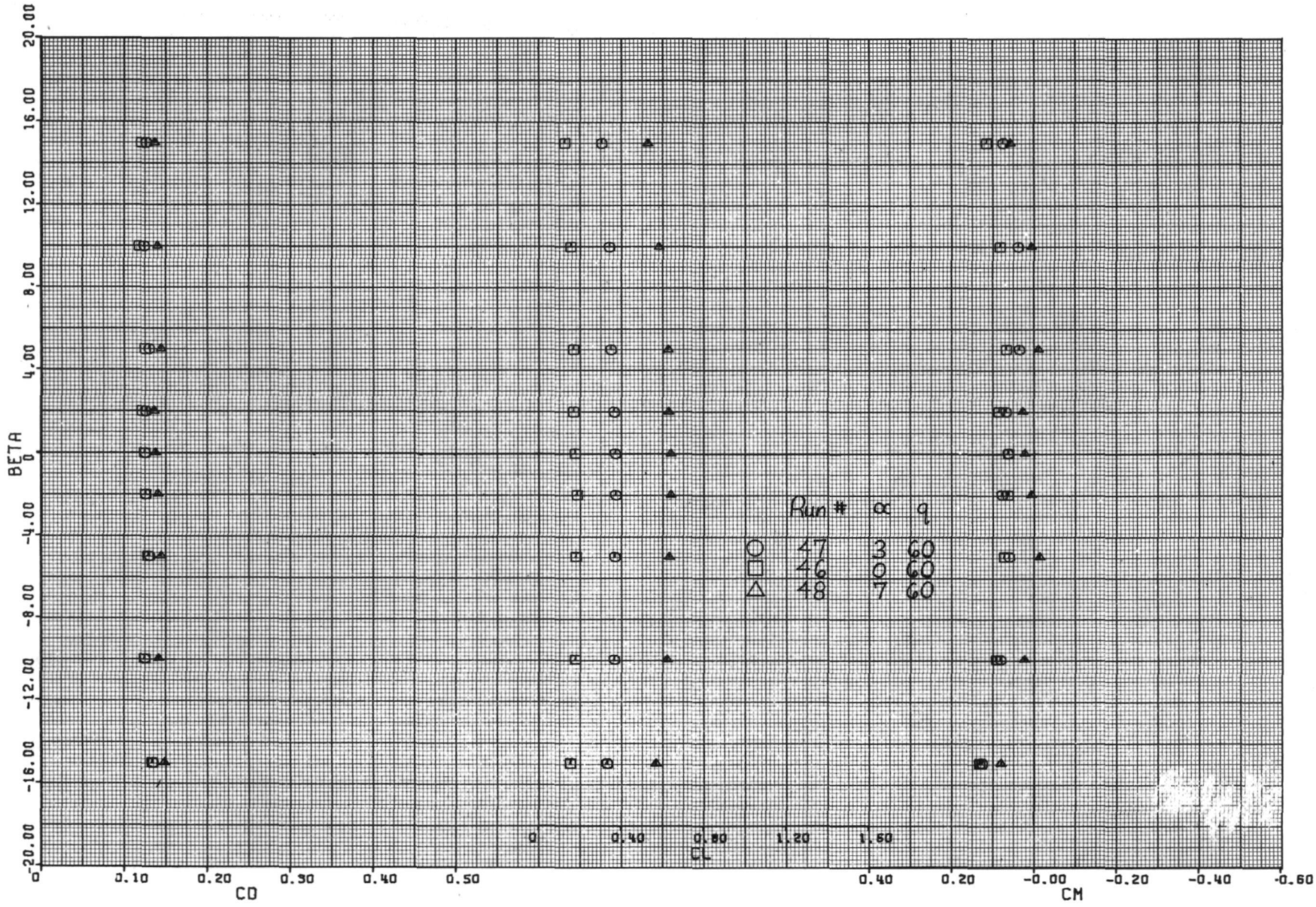
(a) Runs 44, 42, 43, 45 – Concluded.

Figure 5.– Continued.



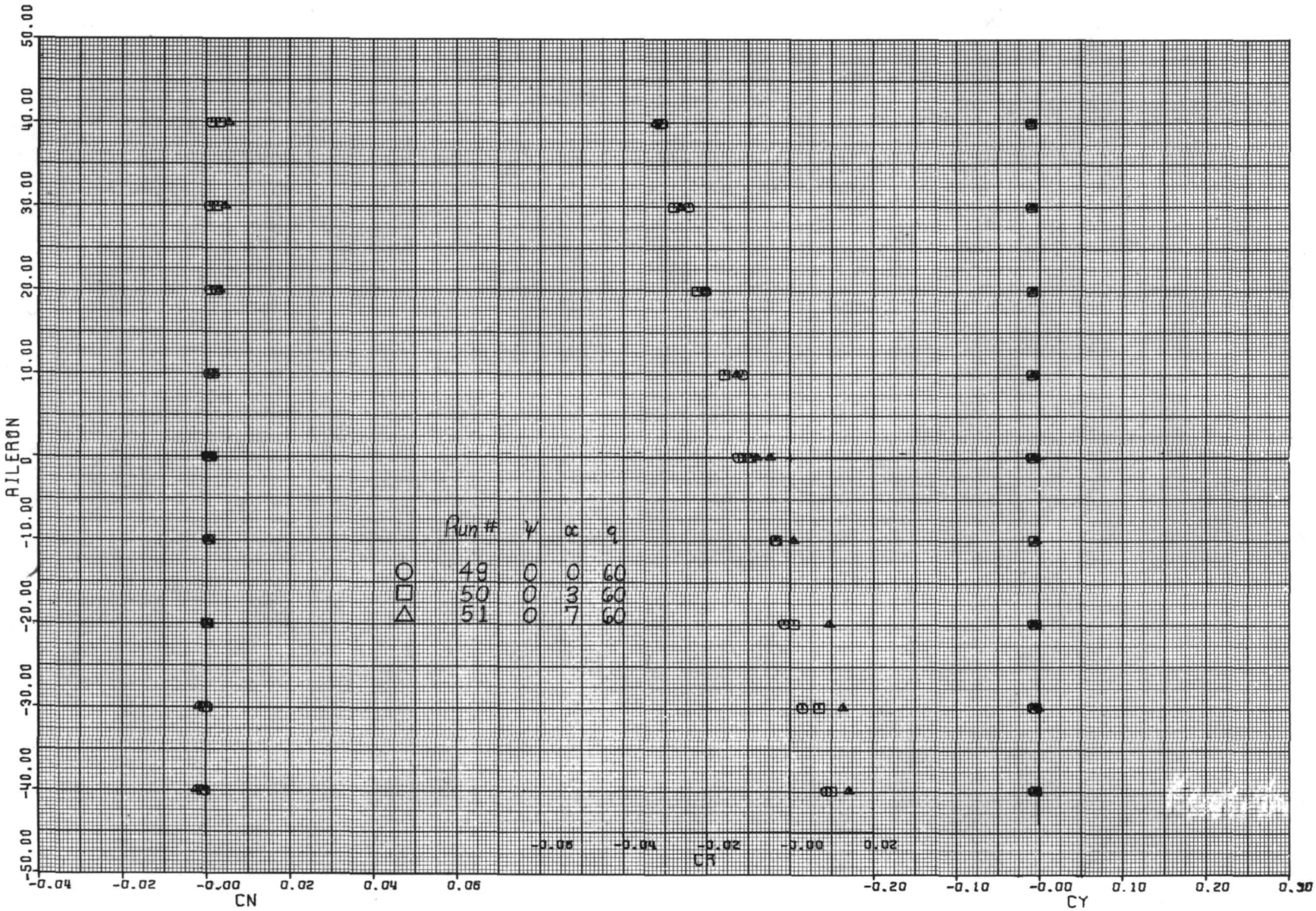
(b) Runs 47, 46, 48.

Figure 5.– Continued.



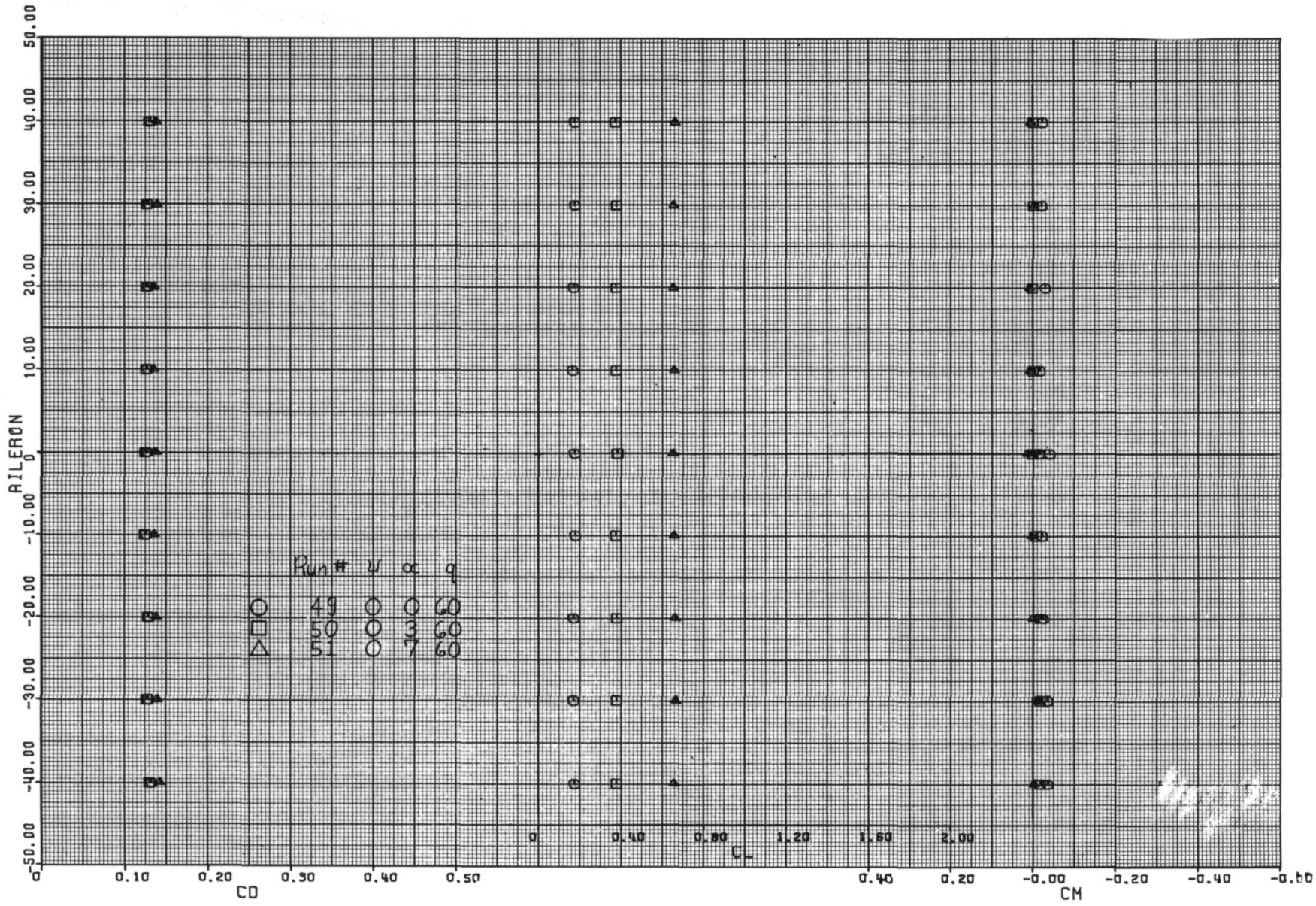
(b) Runs 47, 46, 48 – Concluded.

Figure 5.– Continued.



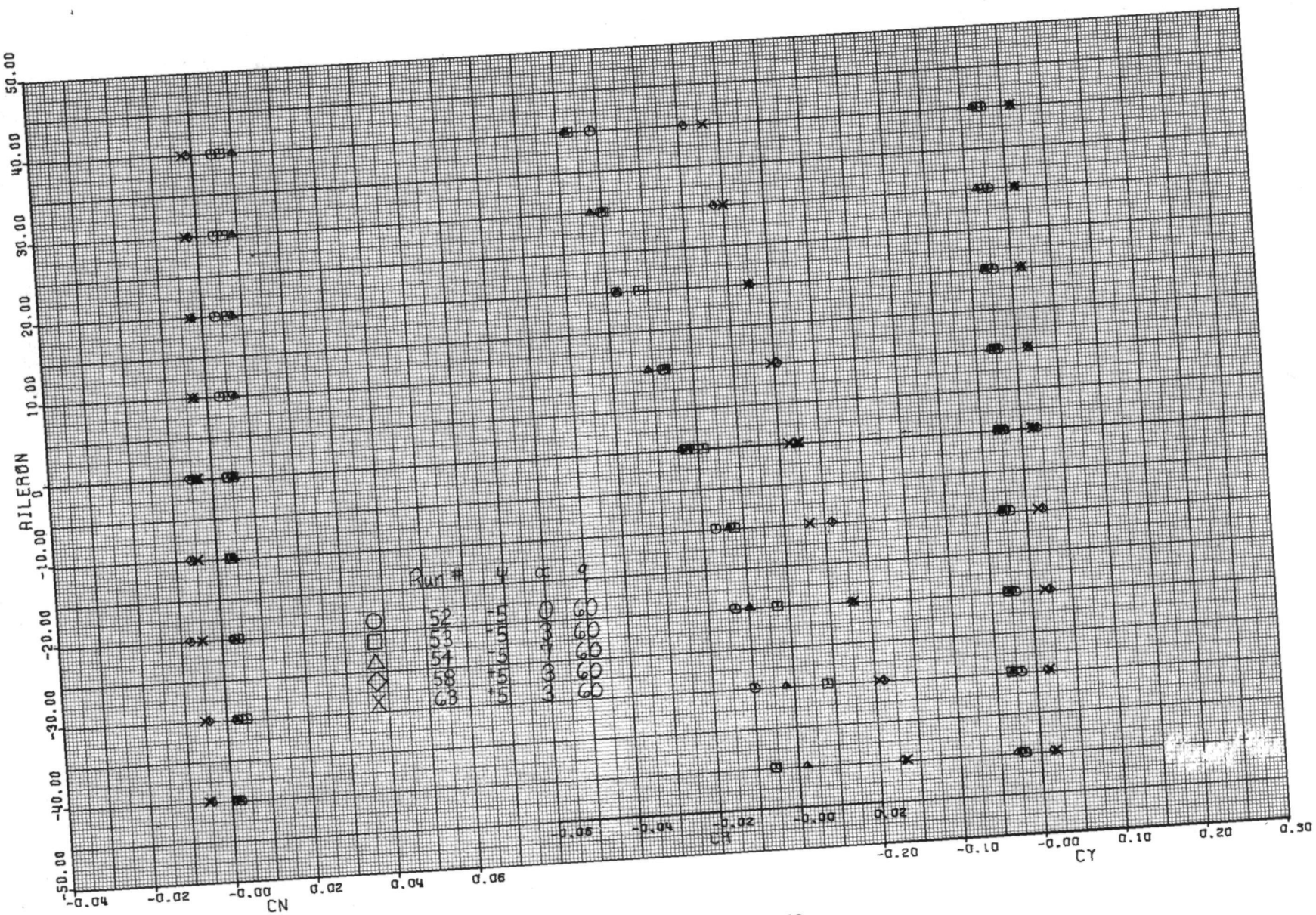
(c) Runs 49, 50, 51.

Figure 5.– Continued.



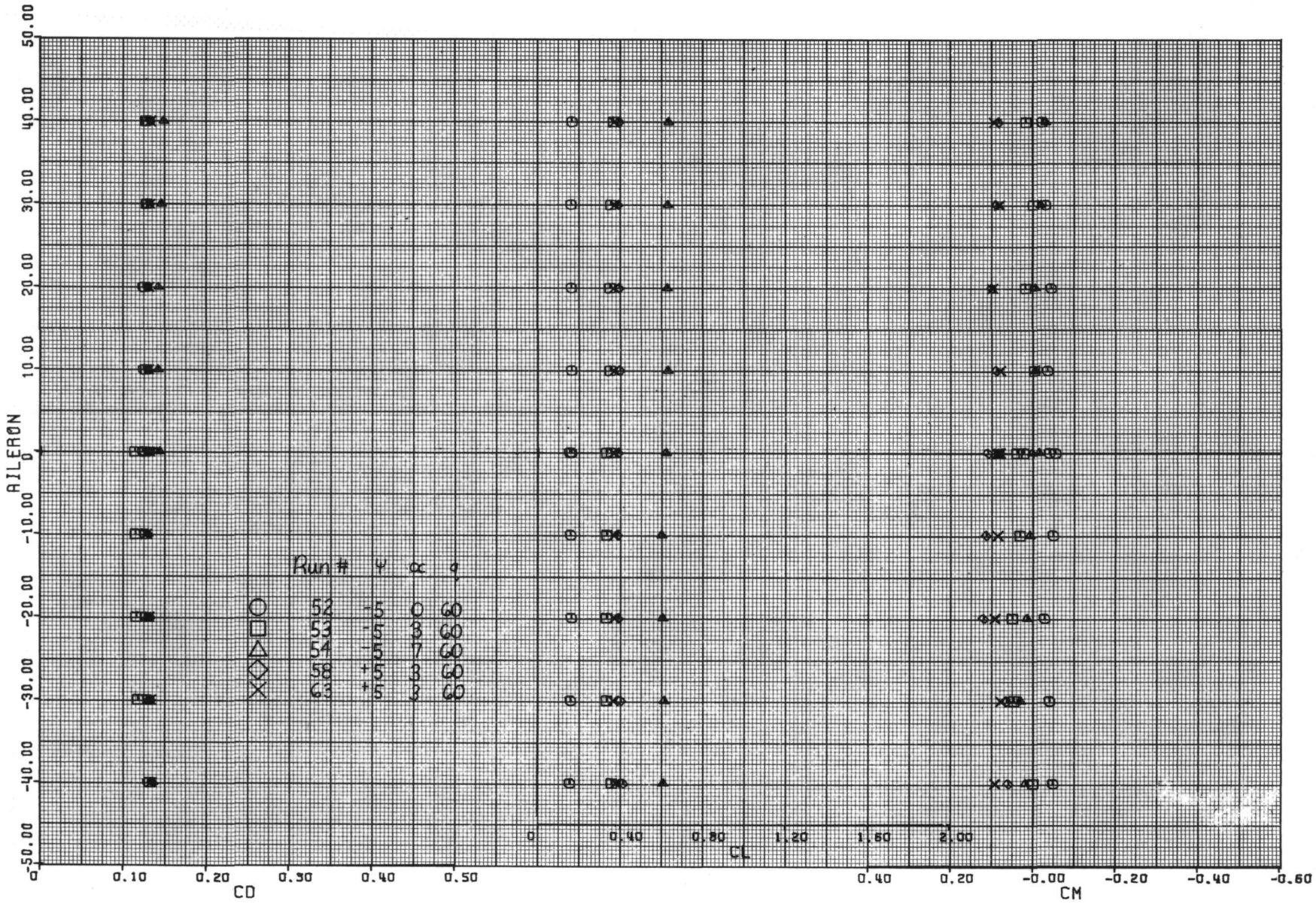
(c) Runs 49, 50, 51 – Concluded.

Figure 5.– Continued.



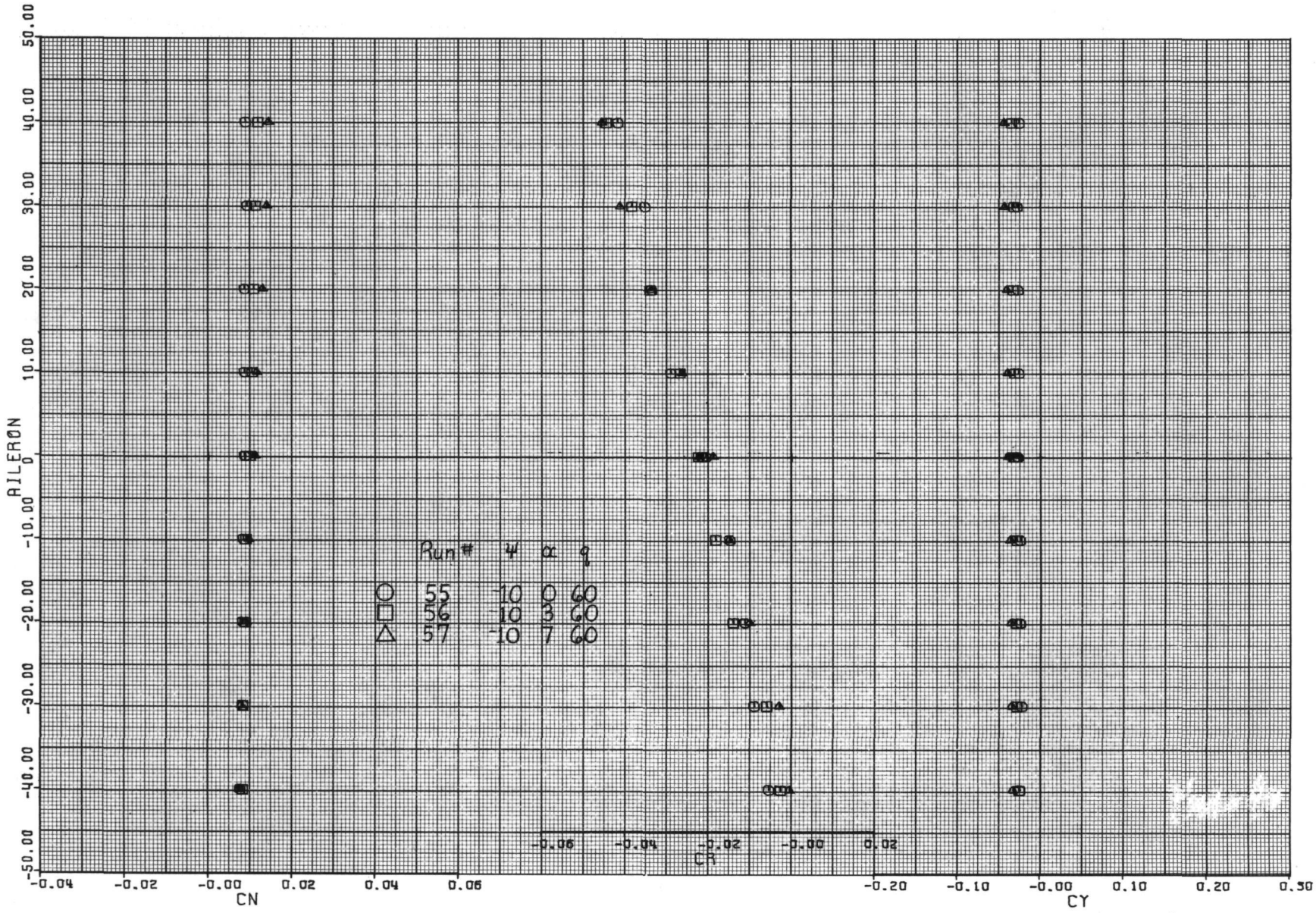
(d) Runs 52, 53, 54, 58, 63.

Figure 5.– Continued.



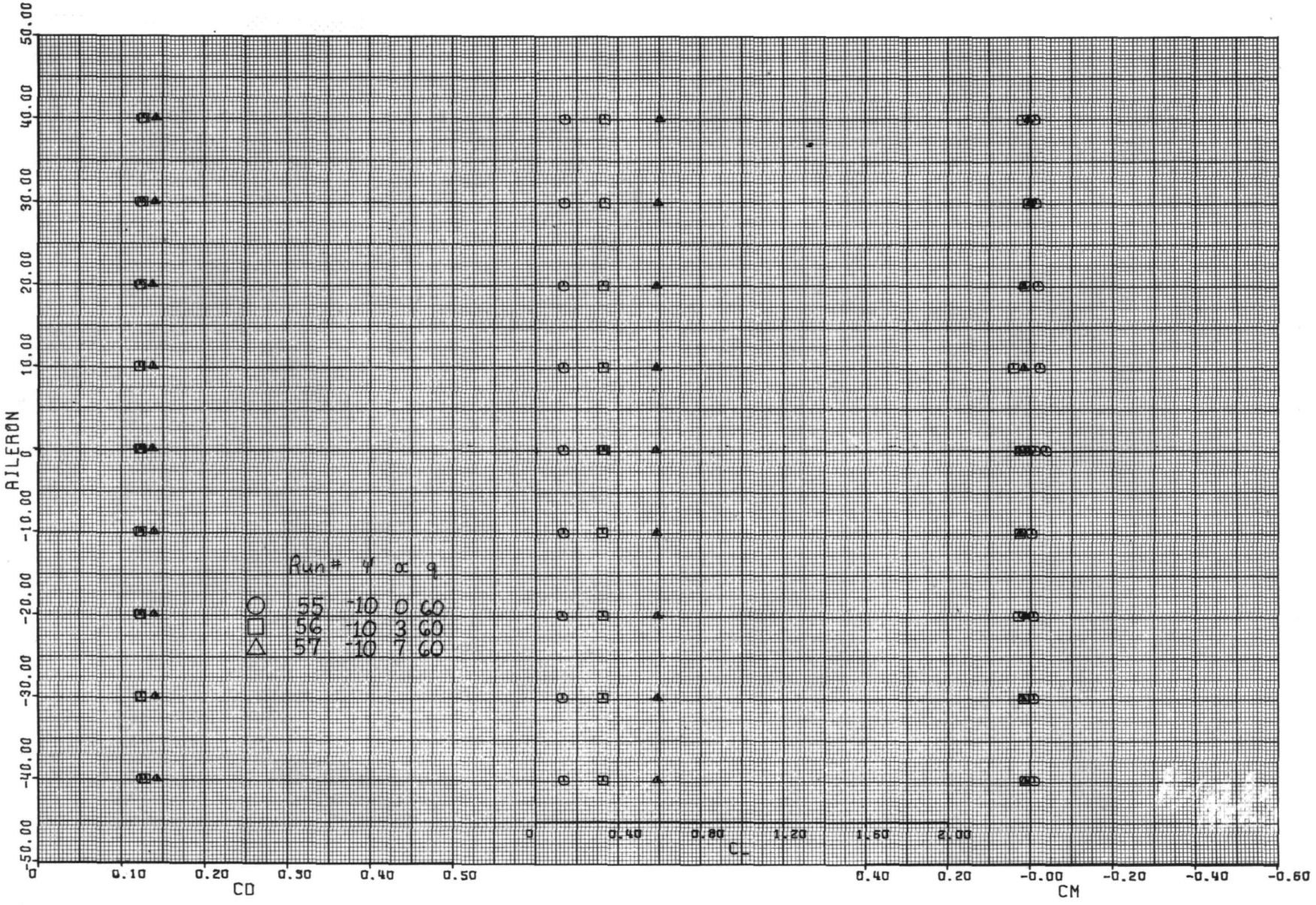
(d) Runs 52, 53, 54, 58, 63 – Concluded.

Figure 5.– Continued.



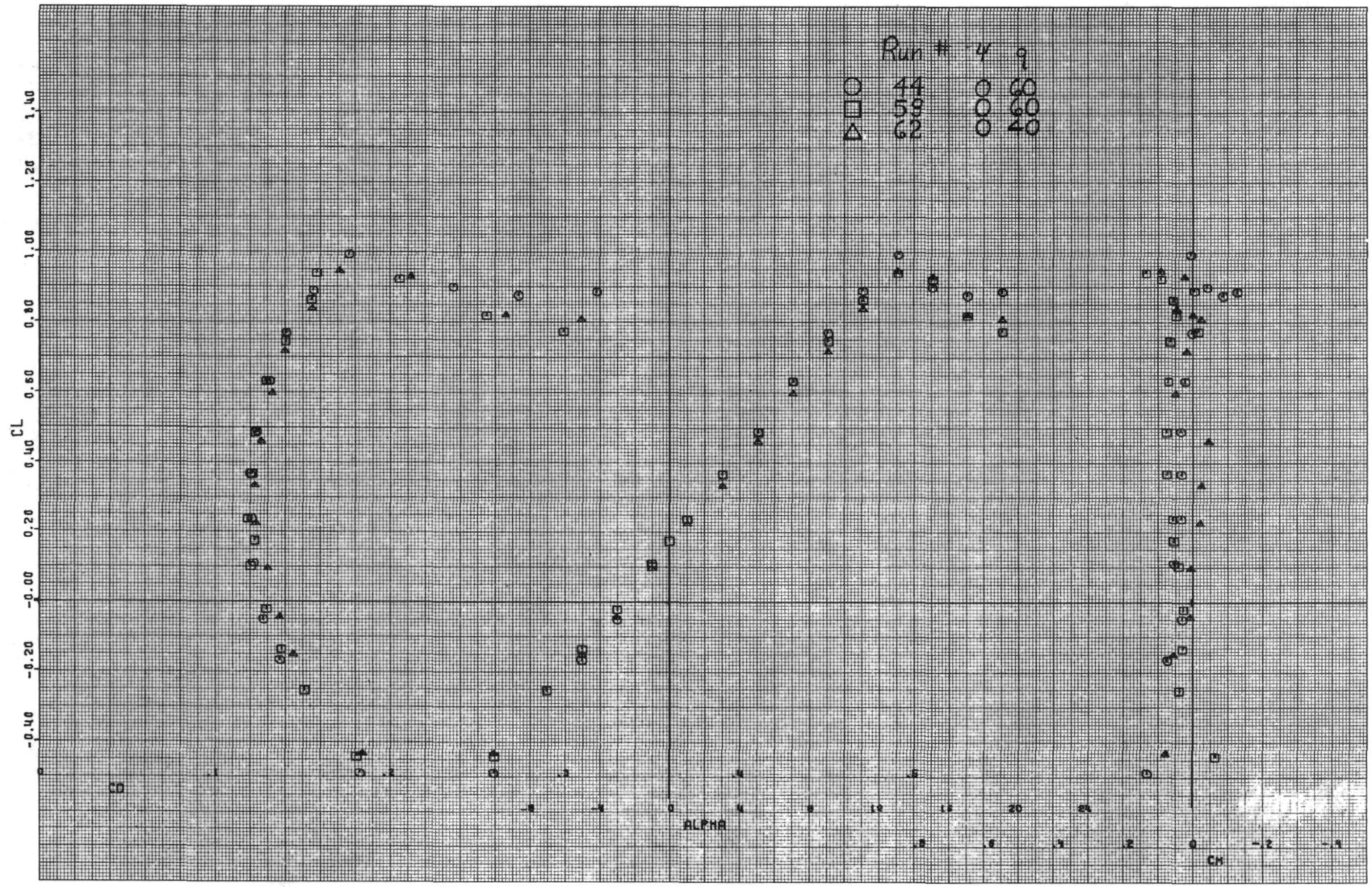
(e) Runs 55, 56, 57.

Figure 5.– Continued.



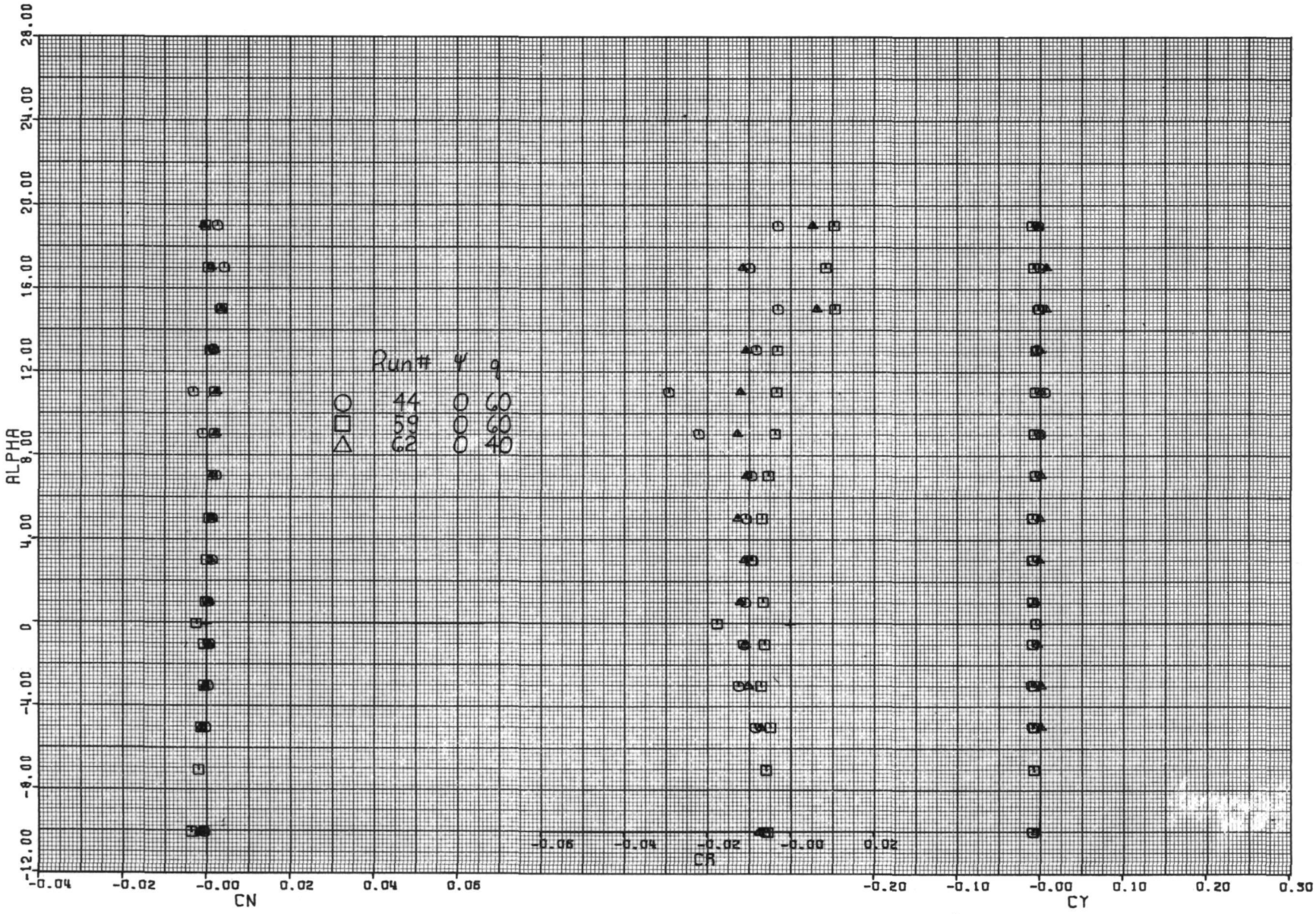
(e) Runs 55, 56, 57 – Concluded.

Figure 5.– Continued.



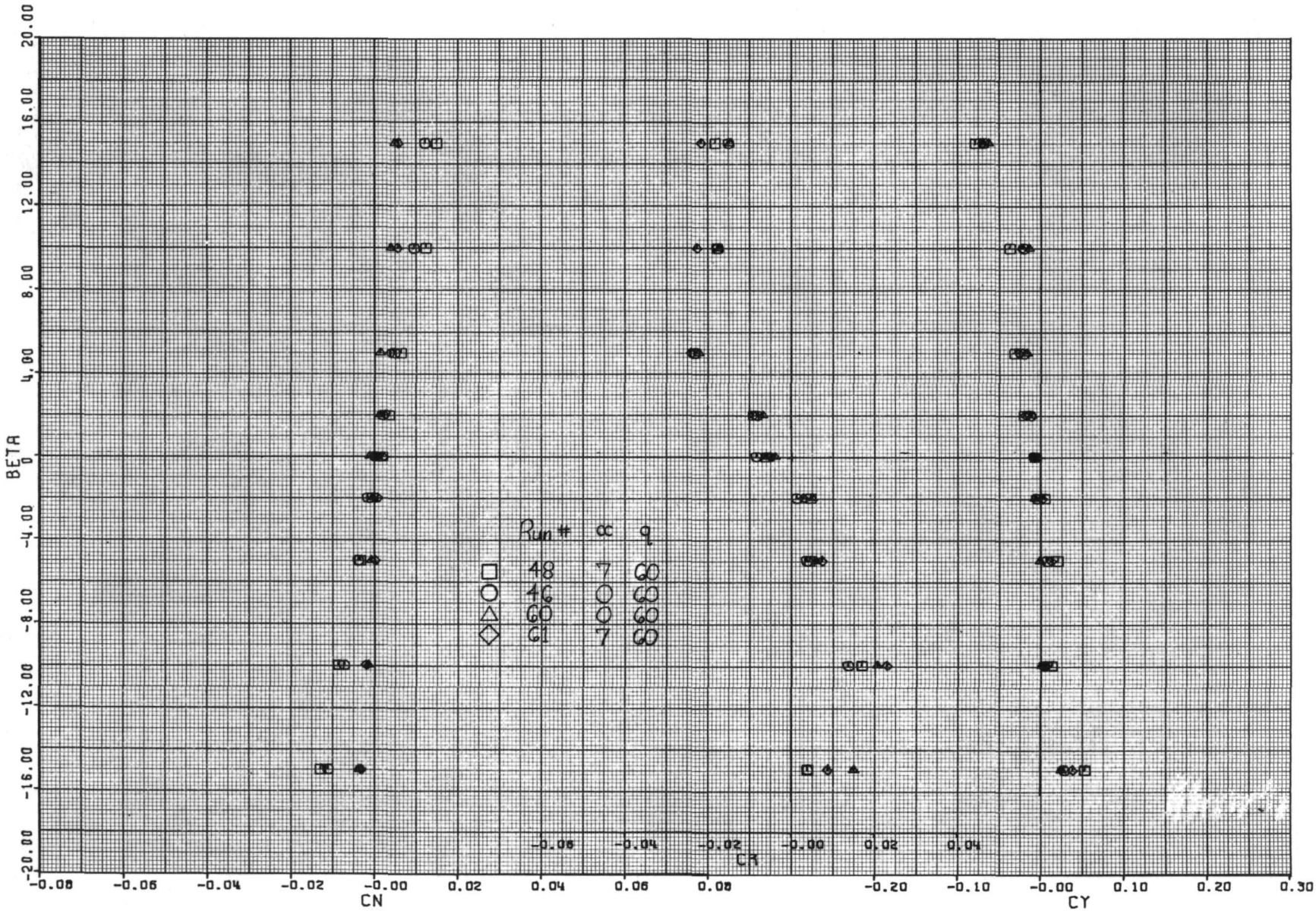
(f) Runs 44, 59, 62.

Figure 5.– Continued.



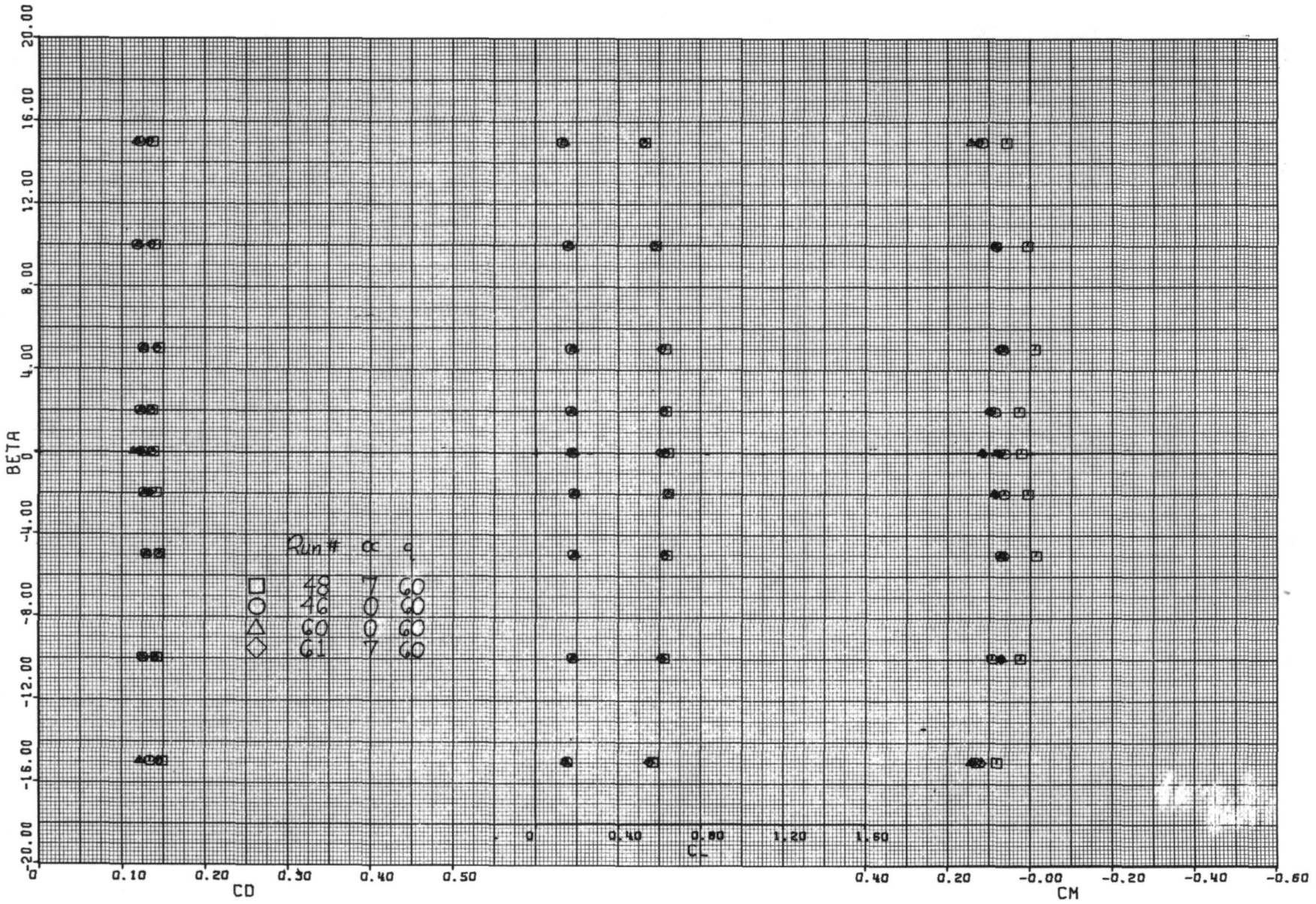
(f) Runs 44, 59, 62 – Concluded.

Figure 5.– Continued.



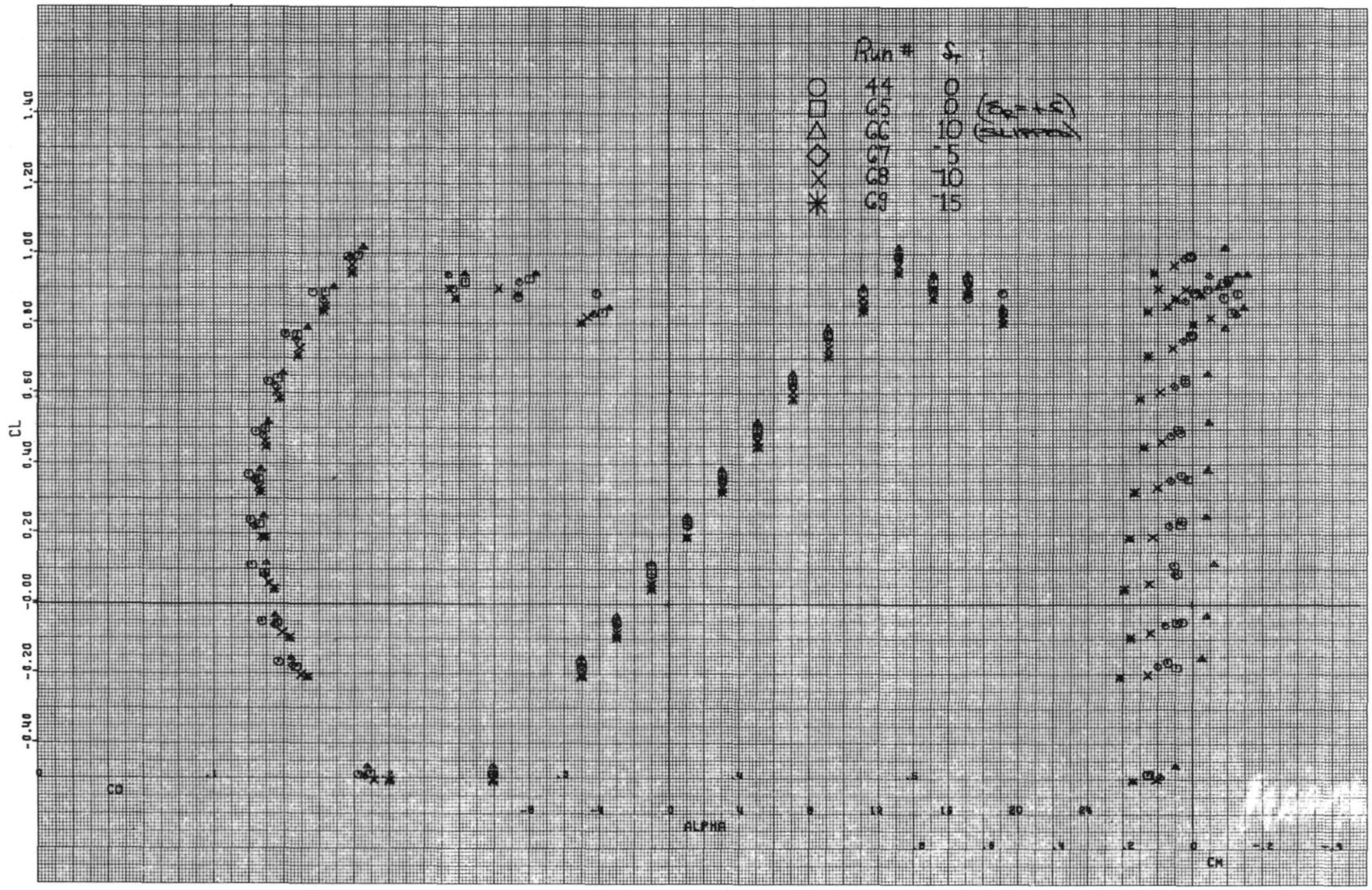
(g) Runs 48, 46, 60, 61.

Figure 5.– Continued.



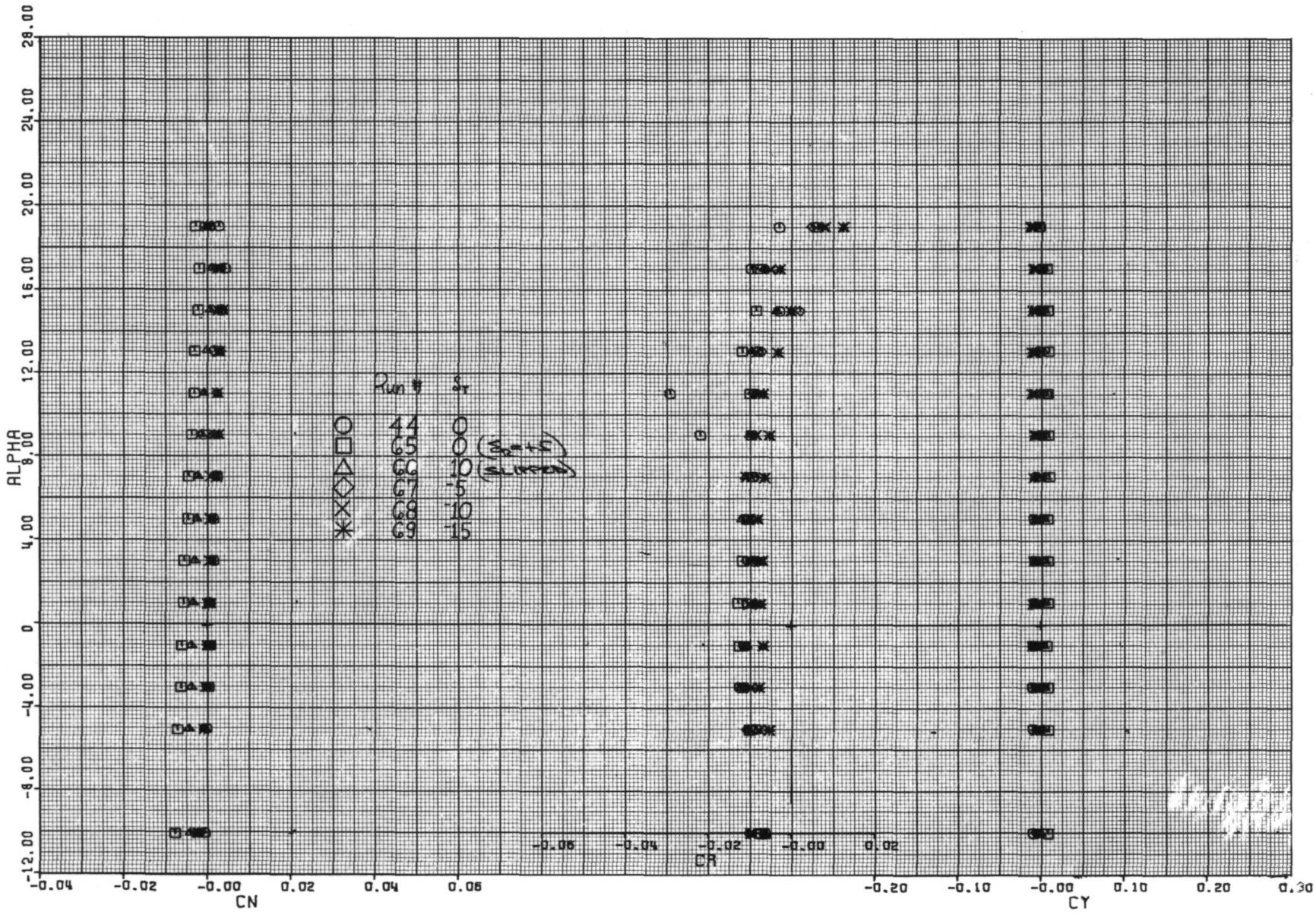
(g) Runs 48, 46, 60, 61 – Concluded.

Figure 5.– Continued.



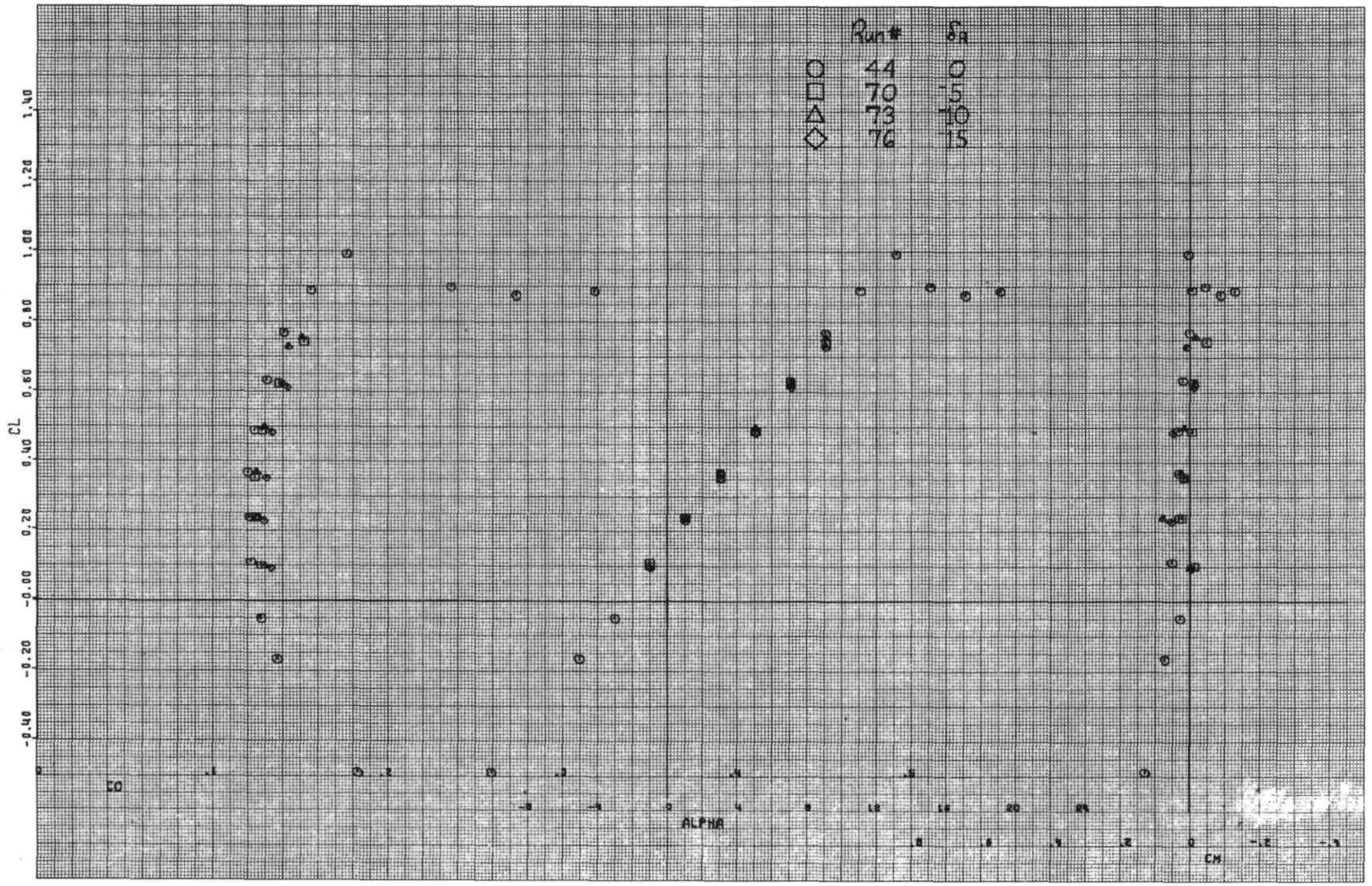
(h) Runs 44, 65, 66, 67, 68, 69.

Figure 5.– Continued.



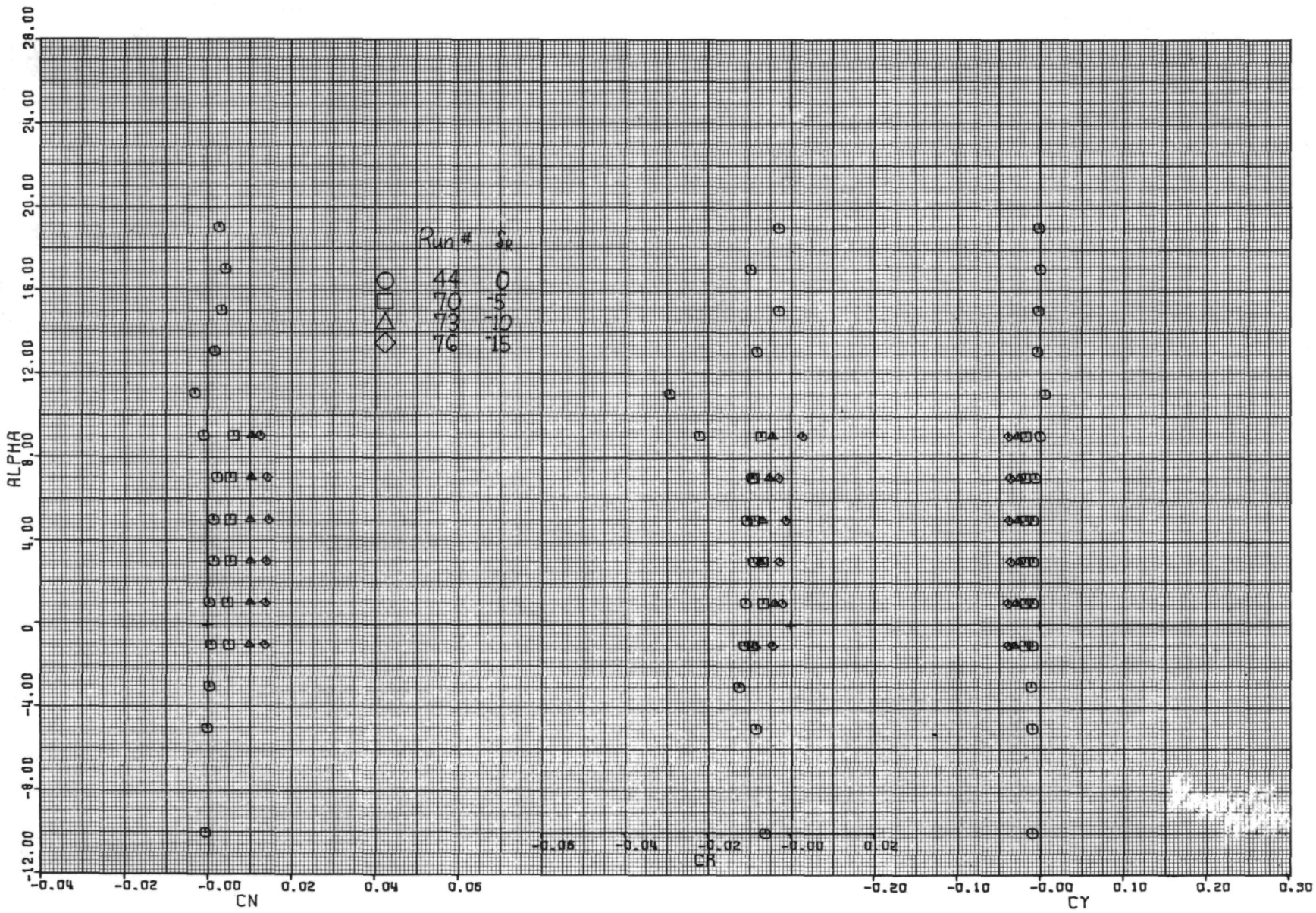
(h) Runs 44, 65, 66, 67, 68, 69 – Concluded.

Figure 5.– Continued.



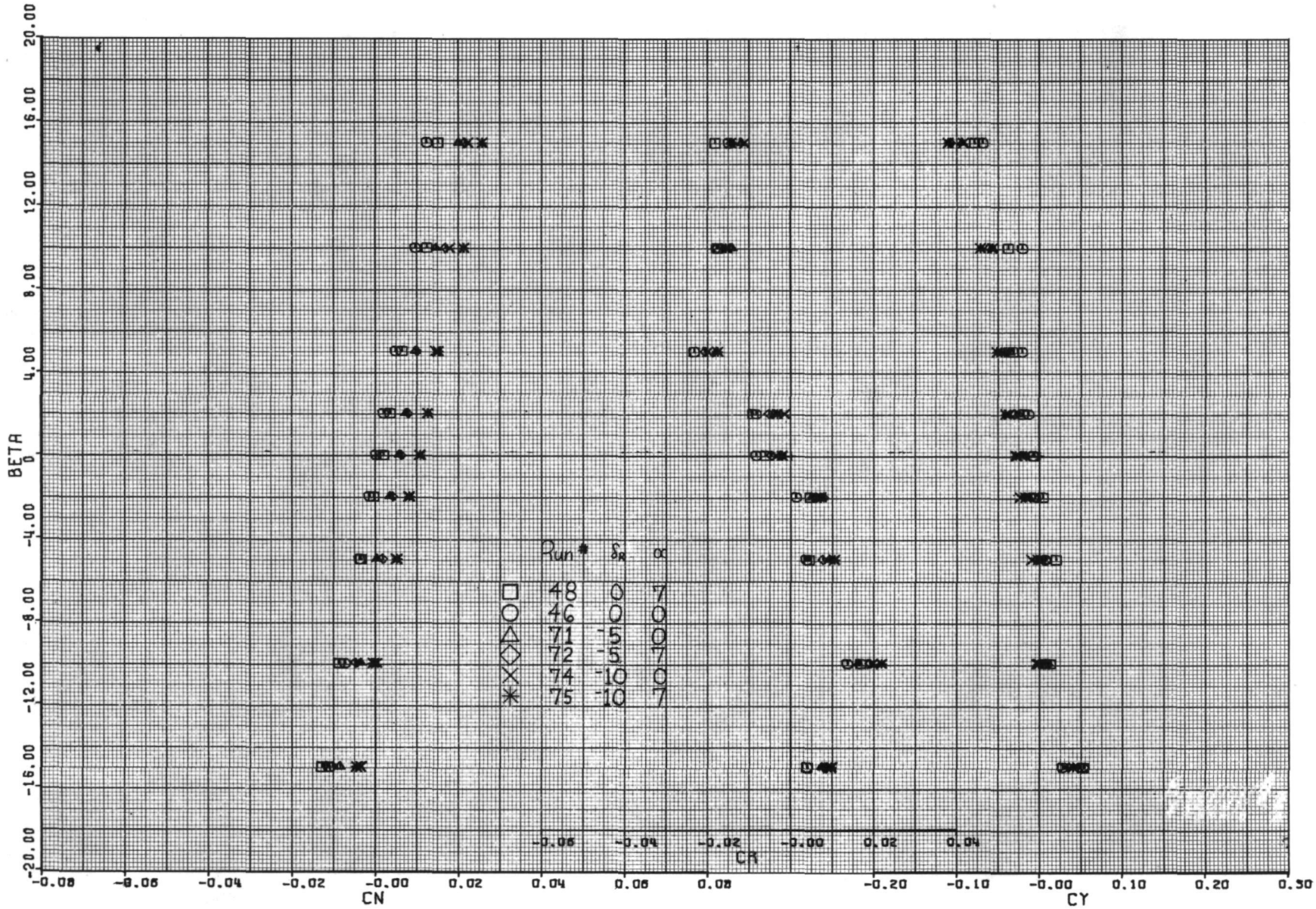
(i) Runs 44, 70, 73, 76.

Figure 5.– Continued.



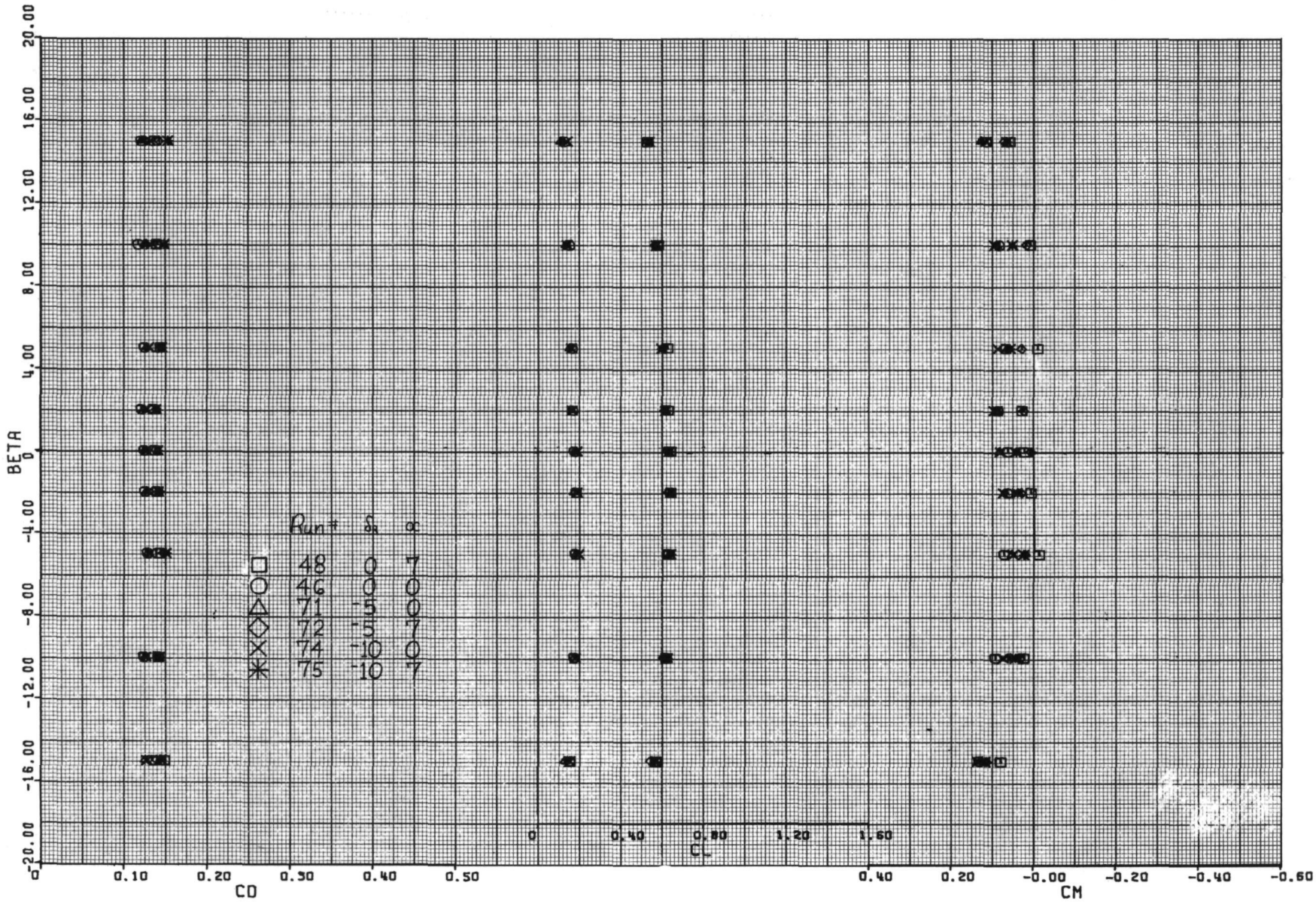
(i) Runs 44, 70, 73, 76 – Concluded.

Figure 5.– Continued.



(j) Runs 48, 46, 71, 72, 74, 75.

Figure 5.– Continued.



(j) Runs 48, 46, 71, 72, 74, 75 – Concluded.

Figure 5.– Concluded.